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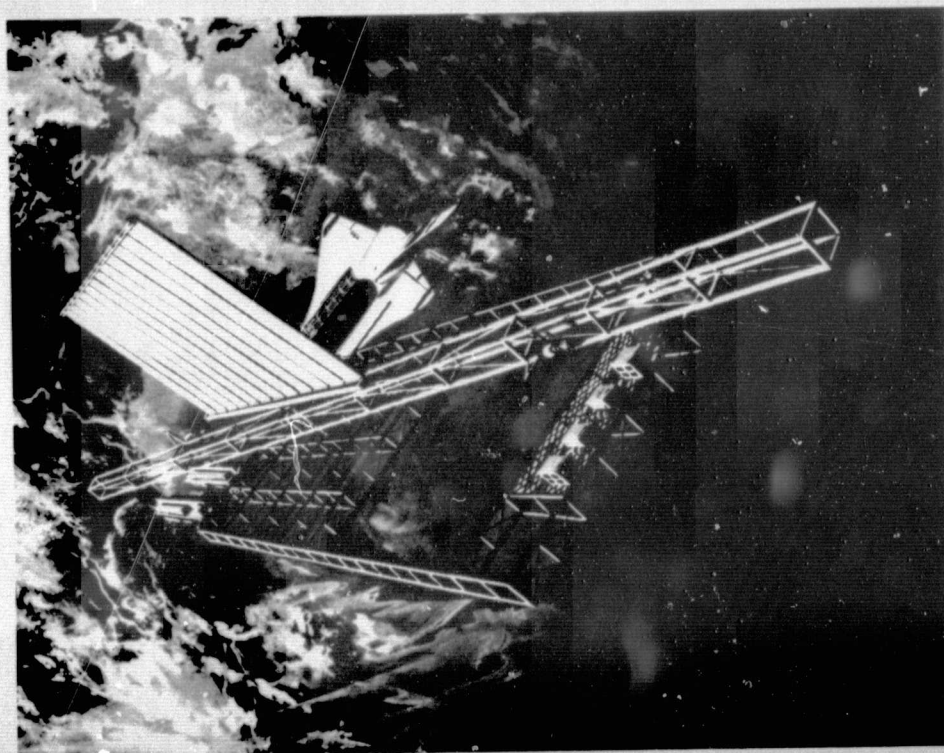
CR 151466

ORBITAL CONSTRUCTION DEMONSTRATION STUDY

VOLUME III REQUIREMENTS DOCUMENT

FINAL REPORT

(CONTRACT NAS 9-14916)



GRUMMAN

**ORBITAL
CONSTRUCTION DEMONSTRATION
STUDY**

**VOLUME III
REQUIREMENTS DOCUMENT**

FINAL REPORT
(CONTRACT NAS 9-14916)

Prepared for

LYNDON B. JOHNSON SPACE CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
HOUSTON, TEXAS 77058

By

GRUMMAN AEROSPACE CORPORATION
BETHPAGE, NEW YORK 11714

FOREWORD

Utilization of space for solar power, communications, and other practical industrial applications requires the orbital construction and assembly of large space structures. Realization of this objective in a cost effective manner requires an orbital facility which can verify and develop the necessary technology and associated data base. This document provides a comprehensive set of requirements that defines the objective, scope and configuration of the orbital test facility needed to demonstrate the necessary automated fabrication, construction and assembly technology. In addition to the requirements for the orbital demonstration facility, a detailed list of experiment requirements are included in Appendix B for these areas of technology:

- Structure
- Solar Array
- Power Distribution
- Power Transmission
- Assembly Operations
- Mission OPS
- Processes
- Propulsion
- Stabilization and Control
- Reflector Mission Facets
- Radiators
- Thermal Cavities
- Large Mirror Surfaces.

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Section 1
PROGRAM REQUIREMENT

The following tabulation establishes the objectives and scope of the program.

REQUIREMENT	RATIONALE/SOURCE
1.1 The orbital demonstration program shall utilize STS elements to demonstrate and evaluate orbit assembly techniques representative of those which may be used in constructing large operational structures in space.	A/2.0/2
1.2 The program shall be representative of the characteristics and requirements of potential operational large space structures.	A/4.1/3
1.3 The program shall include structural approaches for potential application in the construction and the maintenance of large space structures referenced in Section 1.2.	A/4.1/3
1.4 The program shall lead to an Orbital Construction Demonstration Article (OCDA) which shall embody structural principles associated with large structures.	A/4.1.a/3
1.5 The OCDA shall employ manned and automated techniques to the extent that cost effective assembly measures are demonstrated.	A/4.1.b/3
1.6 Incorporate maintenance procedures and techniques to assure an OCDA life of 10 years.	A/4.1.c/4 (MOD)
1.7 The OCDA shall be designed to operate in a 350 km orbit of 28° inclination.	A/4.1.d/4 (MOD)
1.8 Provisions shall be provided to implement representative potential scientific investigation, domestic applications programs and continued utility as a demonstration facility.	A/4.1.e/4 (MOD)

REQUIREMENT	RATIONALE/SOURCE
1. 9 The OCDA shall be designed to require in-orbit assembly and qualification of applicable techniques, but should be limited in size or complexity in the cause of cost effective achievement of the demonstration objectives.	A/5. 1/6
1. 10 A minimum of two Shuttle flights are required for initial placement of the OCDA.	A/5. 2/6
1. 11 Additional periodic revisitation Shuttle flights are required to investigate multimission logistics and orbital operations and to further the continued utility of the demonstration system.	A/5. 2/6
1. 12 Shuttle flights shall be limited to no more than six for any calendar year.	
1. 13 The OCDA shall be responsive to continued use and growth for continuing investigation of assembly techniques and the further development of the utility embodied in the demonstration system.	A/5. 3/7
1. 14 The OCDA mission shall be conducted in an orbit within the performance envelope of the Shuttle; assembly techniques and procedures shall include those applicable to assembly in any earth orbit.	A/5. 4/7
1. 15 The OCDA assembly techniques and procedures shall demonstrate fastening techniques, alignment methods, procedures development, execution control/verification, dynamic stabilization, thermal control and maintenance provisions.	A/4. 1. b/4
1. 16 The IOC date shall be 1984.	JSC

Section 2
MISSION REQUIREMENTS

The following tabulation defines the mission requirements.

REQUIREMENT	RATIONALE/SOURCE												
2.1 Reference Missions 2.1.1 Mission: The basic reference mission is to demonstrate and evaluate the ability to build an orbital construction demonstration article (OCDA) which incorporates structural principles (e.g., types of structures, materials, technologies and assembly/construction techniques) most representative in the construction of large structures in space. The OCDA structure will be built up out of the basic building block structure divided between aluminum and composites. The representative structures which will be incorporated into the OCDA are: <table> <tr> <th data-bbox="388 1166 757 1198"><u>Representative Structure</u></th><th data-bbox="791 1119 1189 1198"><u>Example of Large Structure Application</u></th></tr> <tr> <td data-bbox="388 1229 757 1315">A. Large Near Planar Array</td><td data-bbox="791 1229 1189 1261">Solar Power Satellite</td></tr> <tr> <td data-bbox="388 1325 757 1453">B. Tight Tolerance Concentrators and Large Radiators</td><td data-bbox="791 1325 1189 1410">Solar-Thermal Power Satellite</td></tr> <tr> <td data-bbox="388 1474 757 1602">C. Critical Thermal Environment/Phased Array</td><td data-bbox="791 1474 1189 1559">Microwave Power Transmission System</td></tr> <tr> <td data-bbox="388 1623 757 1751">D. Complex Form/Tight Tolerance Surface Requirement</td><td data-bbox="791 1623 1189 1655">Radiometer Reflector</td></tr> <tr> <td data-bbox="388 1772 757 1847">E. Large Stretched Membrane</td><td data-bbox="791 1772 1189 1804">Solar Mirror</td></tr> </table>	<u>Representative Structure</u>	<u>Example of Large Structure Application</u>	A. Large Near Planar Array	Solar Power Satellite	B. Tight Tolerance Concentrators and Large Radiators	Solar-Thermal Power Satellite	C. Critical Thermal Environment/Phased Array	Microwave Power Transmission System	D. Complex Form/Tight Tolerance Surface Requirement	Radiometer Reflector	E. Large Stretched Membrane	Solar Mirror	A/2.0/2 A/4.1/3 L/5.1/5-1 L/Fig. 2-2/2-2
<u>Representative Structure</u>	<u>Example of Large Structure Application</u>												
A. Large Near Planar Array	Solar Power Satellite												
B. Tight Tolerance Concentrators and Large Radiators	Solar-Thermal Power Satellite												
C. Critical Thermal Environment/Phased Array	Microwave Power Transmission System												
D. Complex Form/Tight Tolerance Surface Requirement	Radiometer Reflector												
E. Large Stretched Membrane	Solar Mirror												

REQUIREMENT	RATIONALE/SOURCE
● Address issues of C/O and fault isolation ● Address operations at 20 to 40 kv ● Address thermal cycling issues. C. <u>Power Distribution System Technologies shall:</u> ● Demonstrate installation of bus system including conductors, power conditioners and switch gear ● Address issues of energy storage for attitude control, system heating, etc. ● Address issues of large rotary joint installation and operation ● Address issues of C/O, fault isolation and repair.	L/ Fig. 5-2/5-3
D. <u>Propulsion Technologies shall:</u> ● Demonstrate on orbit installation of low thrust propulsion systems for orbit keeping and attitude control ● Address issues of propellant resupply ● Address issues of exhaust contamination of solar array ● Assess Ion engine capability for station-keeping function.	L/ Fig. 5-3/5-3
E. <u>Stabilization and Control shall:</u> ● Address control of large flexible structure including location of sensors and actuators ● Address control of configurations with changing geometry during construction and during operations ● Address design of rotary joint control and accuracy.	L/ Fig. 5-3/5-3

REQUIREMENT	RATIONALE/SOURCE												
2.1.2 <u>Orbit</u> : The OCDA shall be assembled and operated in a circular orbit of 350 km altitude with an inclination of 28°.													
2.1.3 <u>Crew Size and Skills</u>													
2.1.3.1 The OCDA shall be assembled with a maximum crew of seven consisting of two three-man construction crews and a crewman for Shuttle operations.	L/Fig. 4-7/4-6												
2.1.3.2 The Shuttle shall provide habitation and crew logistics during OCDA assembly and operations.													
2.1.3.3 An OCDA workday shall consist of two, ten-hour shifts.													
2.1.3.4 Maximum daily EVA time per crewman shall not exceed six hours.													
2.1.4 <u>Transportation</u>													
2.1.4.1 The STS shall be the OCDA launch vehicle.													
2.1.4.2 The STS will be launched from KSC and will deliver the OCDA and associated experiments into a 350 km circular orbit with a 28° inclination.													
2.1.4.3 The STS payload delivery capability for the orbit defined in Section 2.1.4.2 is as follows:													
<table><tr><th colspan="2"><u>Payload</u></th><th><u>Type Operation</u></th></tr><tr><th><u>Mass</u></th><th><u>Volume</u></th><td></td></tr><tr><td>29484 kg</td><td>300 cu m</td><td>Delivery Only</td></tr><tr><td>29484 kg</td><td>300 cu m</td><td>Delivery and Rendezvous</td></tr></table>	<u>Payload</u>		<u>Type Operation</u>	<u>Mass</u>	<u>Volume</u>		29484 kg	300 cu m	Delivery Only	29484 kg	300 cu m	Delivery and Rendezvous	O/Fig. 3-3/3-13 O/Fig. 3-6/3-16
<u>Payload</u>		<u>Type Operation</u>											
<u>Mass</u>	<u>Volume</u>												
29484 kg	300 cu m	Delivery Only											
29484 kg	300 cu m	Delivery and Rendezvous											
2.1.5 <u>Mission Duration</u>													
2.1.5.1 Normal mission duration shall be seven days.	L/Fig. 4-7/4-6												
2.1.5.2 Shuttle flights shall be limited to no more than six for any calendar year.	A/5.2/6												

REQUIREMENT		RATIONALE/SOURCE
2.1.5.3 The OCDA shall be designed for initial deployment with two to six Shuttle flights. Additional flights will be required for periodic revisitation to investigate multimission logistics and orbital operations and to further develop the continued utility of the OCDA.		A/5.2/6
2.2 Orbiter Related Performance		
2.2.1 The Shuttle shall provide habitation and logistics for a four man crew and consumables for 28 man-days plus 4 man-days contingency.		O/2.0.b/2.3
2.2.2 Habitation, logistic and consumable requirements in excess of Section 2.2.1 shall be provided by the Shuttle and chargeable to payload.		O/2.0.b/2.3
2.2.3 Payload chargeable requirements shall include, but not be limited to, the following:		
<u>Item</u>	<u>Requirement</u>	
Docking Module	1769 kg for all missions	O/Table 3.13/3-48
Crewman	90.4 kg/man in excess of four men	O/Table 3.13/3-48
Crew Equipment	84.6 kg/man in excess of four men	O/Table 3.13/3-48
Crew Consumables	In excess of 32 man-days	
- Food	See Figure 2-1	P/2/30
- LiOH	See Figure 2-2	P/2/29
- LO ₂	See Figure 2-3	P/2/31
- N ₂	See Figure 2-4	P/2/32
- H ₂ O	5.15 kg/man-day above 32 man-days	N/Table 2/386
EMU Hardware	92 kg/man in excess of two men	O/Table 3.13/3-48
Metabolic Waste Collection	0.19 kg/man-day in excess of 210 man-days	N/Table 2/386

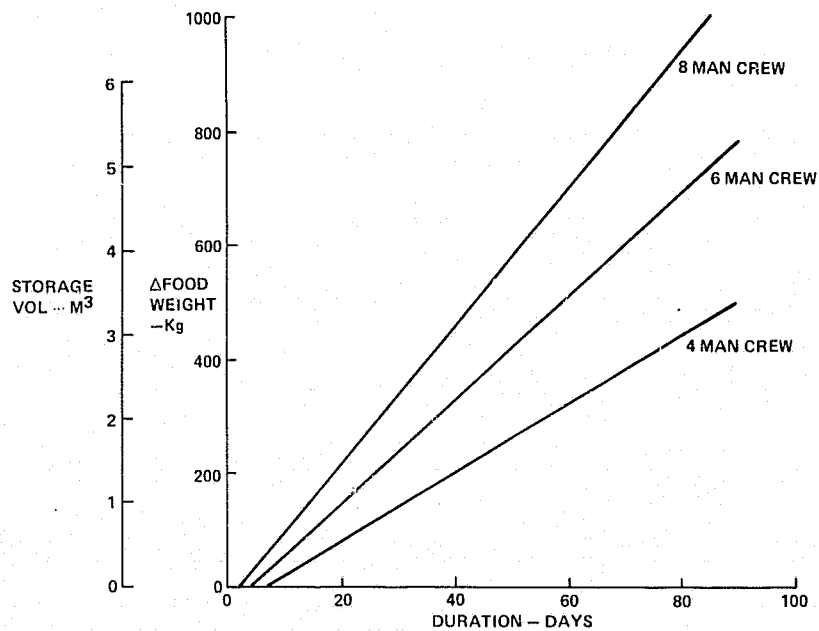


Figure 2-1 Extended Duration Orbiter—Food Requirements Above Baseline

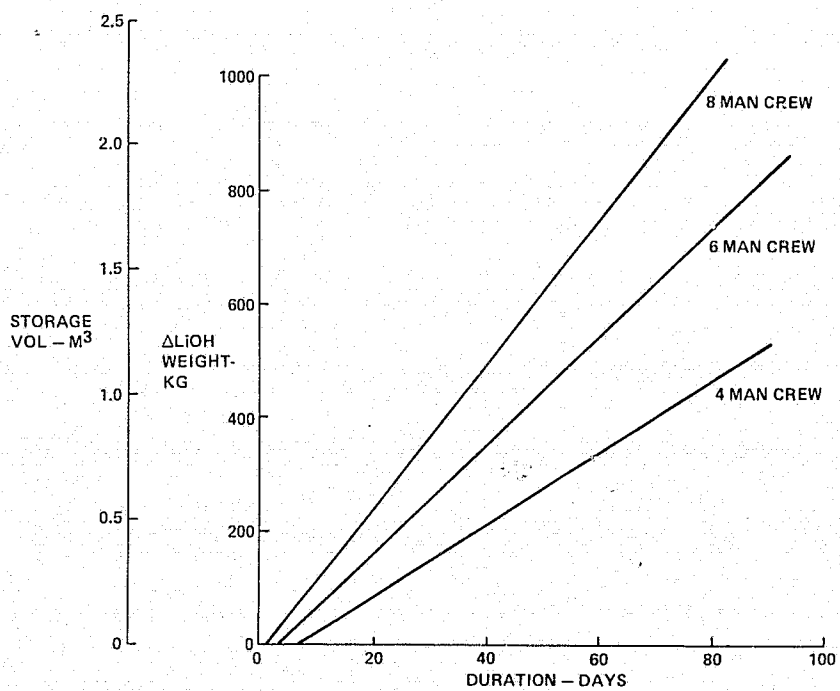


Figure 2-2 Extended Duration Orbiter—LiOH Requirements Above Baseline

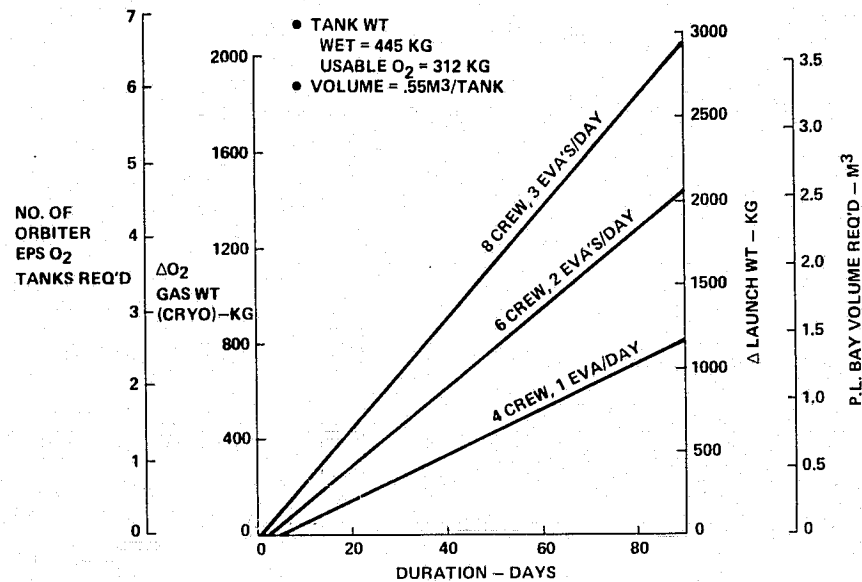


Figure 2-3 Extended Duration Orbiter-Crew O₂ Requirements Using EPS O₂ Tanks for Storage

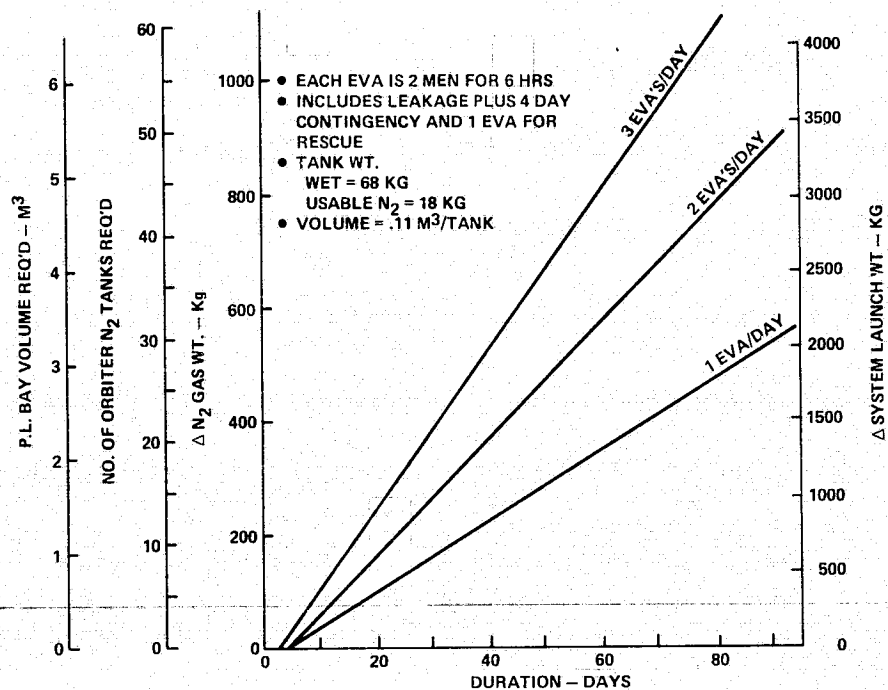


Figure 2-4 Extended Duration Orbiter-N₂ Requirements Using Additional Orbiter N₂ Tanks for Storage

REQUIREMENT		RATIONALE/SOURCE
<u>Item</u>	<u>Requirement</u>	
Waste Water Storage	5.55 kg/man-day in excess of 28 man-days	N/Table 2/386
Sleep Accommodations	1 bed/man in excess of four men	N/3.4/385
Recreation and Exercise	22.6 kg for missions in excess of seven days	N/3.5/385
RCS Propellant	See Figure 2-5	P/2/27
Free Volume	See Figure 2-6	P/2/33
Food Management	393 kg for missions in excess of seven days	N/3.6/365
- Refrigerator, Freezer, Ovens		
Electrical Power	13 kw continuous supplied by OCDA	Q/ /189
2.3 Operations		
2.3.1	The OCDA shall be capable of operating in an unattended mode for periods up to six months.	B/2.01/3
2.3.2	The OCDA shall be capable of operating in both single and multiple shift modes.	B/2.04/3
2.3.3	OCDA status information shall be available as follows:	B/2.06/3 (M)
2.3.3.1	To both the ground and the Shuttle to conform the functional capabilities of operational subsystems prior to manning.	
2.3.3.2	Periodically to the ground for long-term trend analysis, logistics planning, etc.	
2.3.3.3	Continuously to the ground during critical or emergency conditions.	
2.3.4	Data for orbit determination and short range ephemeris predictions shall be provided via the TDRSS.	B/2.07/3
2.3.5	The OCDA shall be a cooperative target during Shuttle/OCDA docking operations.	

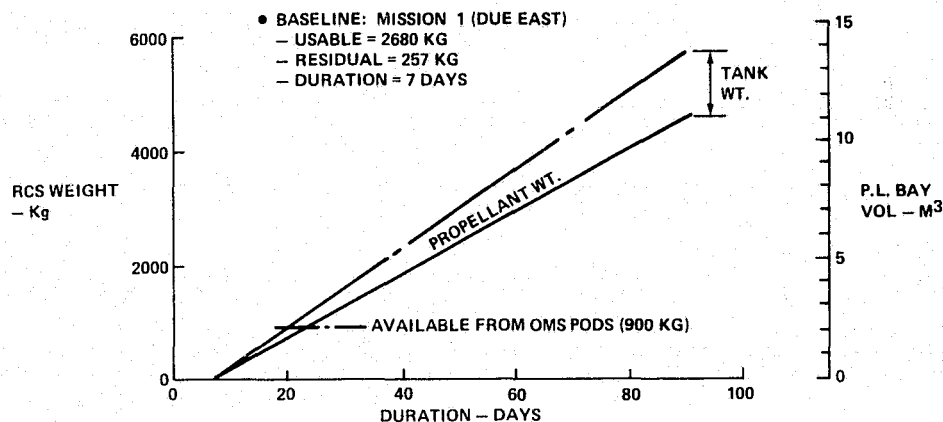


Figure 2-5 Extended Duration Orbiter-RCS System Requirements Above Baseline

REQUIREMENT	RATIONALE/SOURCE
2.3.6 Crew transfer between the Shuttle and the OCDA (except in emergency conditions) shall be EVA through the docking module.	B/2.09/4
2.3.7 Berthing of modules to the OCDA shall be done only when the Shuttle is docked to the OCDA.	B/2.08/4
2.3.8 The OCDA shall have a minimum orbital lifetime of ten years.	
2.3.9 Normal OCDA operations (assembly, construction, experiment) shall be accomplished by machines controlled by the Shuttle with minimum EVA assistance by man.	L/4.4.2/4.5
2.3.10 OCDA experiment operations can be either shuttle or ground controlled.	

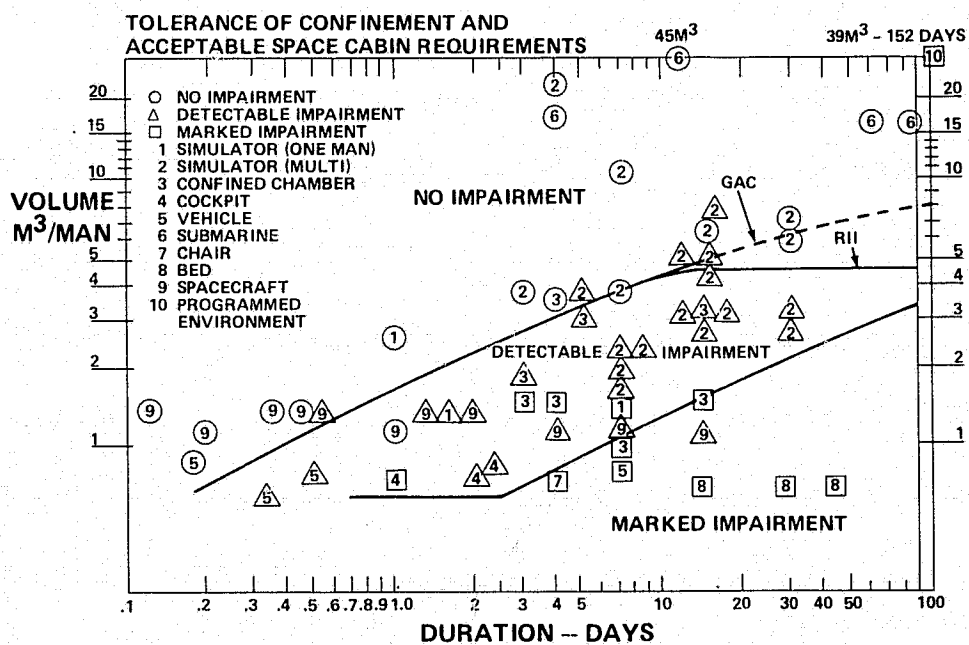


Figure 2-6 Free Volume—Duration Tolerance Factors in Confinement

Section 3

SYSTEM REQUIREMENTS

The following tabulation defines the overall configuration, safety, reliability, maintenance, interface and subsystem requirements.

REQUIREMENT	RATIONALE/SOURCE
3.1 Configuration 3.1.1 The baseline configuration defined in Figure 3-1 shall consist of four major assemblies: 3.1.1.1 Platform 3.1.1.1.1 The platform shall have a 32 m x 72 m platform and a depth of 4 m. The platform shall be constructed of 4 m and 8 m length structural members, which are assembled into 8 m x 8 m and 4 m x 8 m bays. The node points at the bay corners shall contain provisions to secure equipment to the platform. 3.1.1.1.2 The platform shall provide a 24 m x 32 m open area to permit the mounting of test equipment such as solar blankets, thin film mirror surfaces, wire mesh and rectenna structures. 3.1.1.2 Core Module/Mast 3.1.1.2.1 The central mast shall consist of 1.4 m square open truss structure, 10.5 m long. It shall be structurally connected to the platform at three levels, to provide a shear, bending and torsional load path between the rotating boom/solar array and the platform.	F/3.0/67 G/2.1/3 G/2.1/3 F/3.0/82

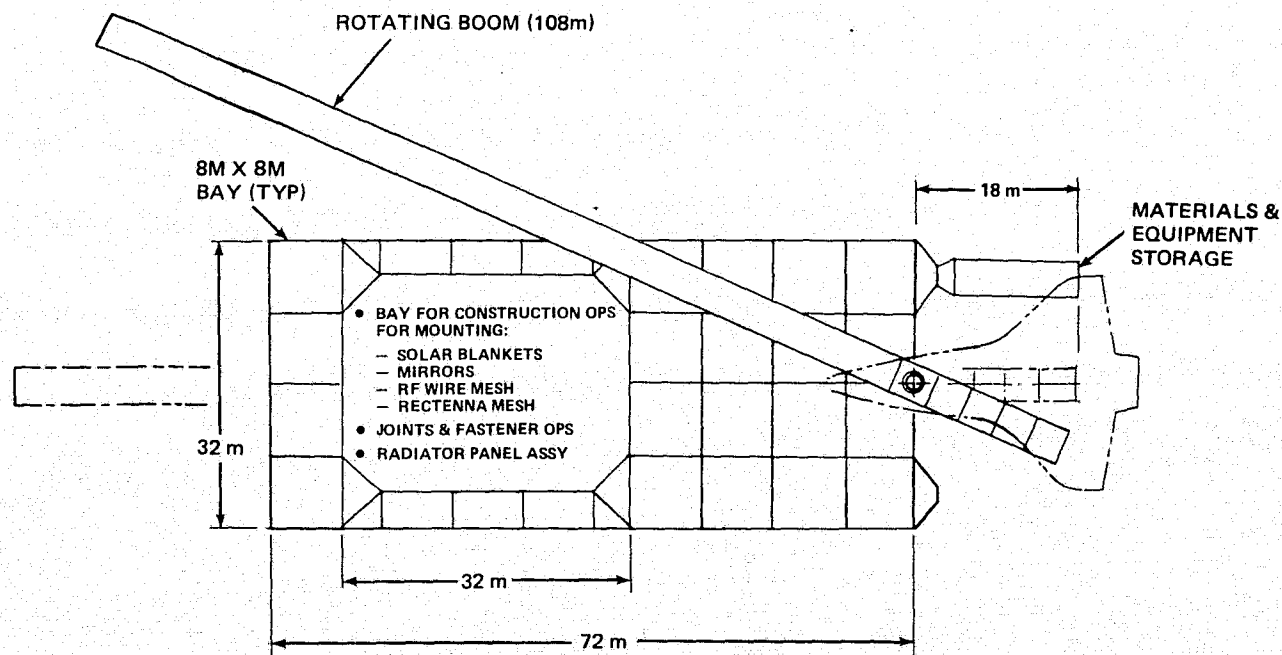
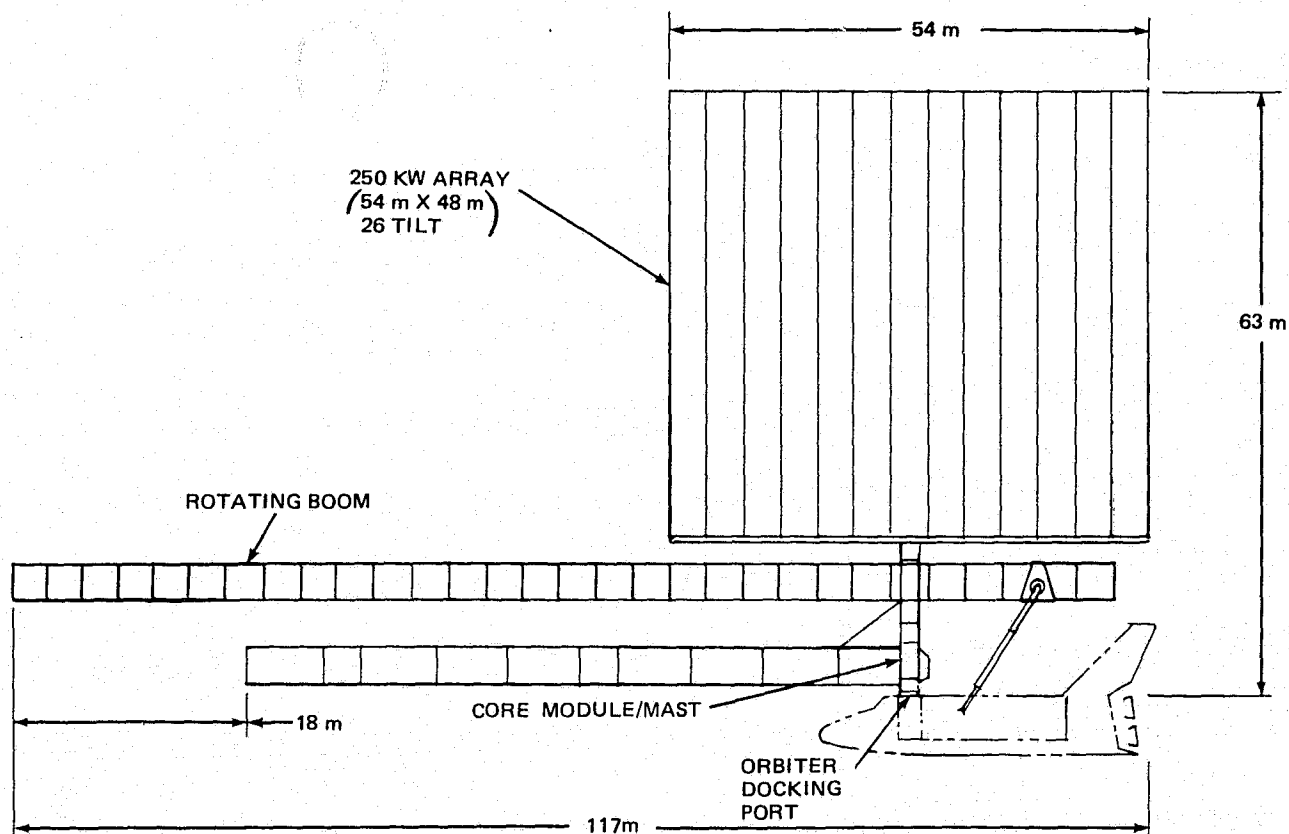


Figure 3-1 General Purpose Demonstration/Test Facility for Construction Technology

REQUIREMENT	RATIONALE/SOURCE
3.1.1.2.2 The Shuttle Docking Module (passive) shall be mounted on the end of the mast. A 1.2 m x 2 m opening shall be provided on the face of the mast for ingress/egress to the orbiter docking module.	F/3.0/82
3.1.1.2.3 Standardized EPS, ACS and CDH multimission modules shall be mounted on the side of the mast, close to the docking ring.	F/3.0/82
3.1.1.2.4 Roll, pitch and yaw reaction wheels shall be mounted midway between the platform and boom.	F/3.0/82
3.1.1.2.5 The Boom/Solar Array Drive Unit shall be mounted on the opposite end of the mast from the Docking Module. It shall interface with a deployable 3.5 m length of the RMS rails/boom and support structure and solar array support structure.	F/3.0/82
3.1.1.3 Rotating Boom: A 4 m square by 108 m long rotating boom, outfitted with a Shuttle manipulator arm and traveller shall be provided to transport equipments and materials to the deck of the main structure and to assist in construction/assembly of large structures within and outside the confines of the OCDA platform.	G/2.1/7
3.1.1.4 Solar Array: The solar array shall consist of a central module and twelve add-on units for an overall size (full array) of 48 m x 54 m. Each module shall use extendable modified (double length) SEPS roll up solar cell blankets. Total/ generated power shall be 250 kw.	F/3.0/86 G/2.1/7
3.1.2 Weight estimates of all OCDA and mission hardware shall include a 20% weight contingency.	B/3.07/5 (M)

REQUIREMENT	RATIONALE/SOURCE
3.1.3 The weight summary for the baseline configuration is defined in Figure 3-2.	C/3.0/3-6
3.1.4 The OCDA shall provide for an orbiter hard-docking capability and module berthing capability to support crew transfer and logistics.	B/3.06/5 (M)
3.1.5 The baseline configuration design loads for the OCDA are as defined in Figure 3-3 through Figure 3-7.	F/4.0/127, 129, 131, 133, 135
3.2 <u>Safety</u>	
3.2.1 No single malfunction or credible combination of malfunctions and/or accidents shall result in the potential of injury to personnel or to abandonment of the OCDA.	B/1.1.1/32
3.2.2 Catastrophic and critical hazards shall be eliminated or controlled.	B/1.1.2/32
3.2.3 The OCDA shall provide the capability for performing critical functions at a nominal level with any single component failed or with any portion of a subsystem inactive for maintenance.	B/2.1/32
3.2.4 The OCDA shall provide the capability to perform critical functions at a reduced level with any credible combination of two component failures, or with any credible combination of a portion of a subsystem inactive for maintenance and failure of a component in the remaining portion of the subsystem.	B/2.2/32
3.2.5 Capability shall be provided for performing critical functions at an emergency level until the affected function can be restored:	B/2.3/32
3.2.5.1 With any module inactivated or isolated and vacated due to a malfunction or accident.	

		<u>LBM</u>	<u>Kg</u>
• CORE MODULE/MAST	(7669)		(3477)
- STRUCTURE		316	143
- DOCKING MODULE (PASSIVE)		320	145
- COMM & DATA HANDLING		270	122
- ELECT POWER		3519 ①	1596
- ACS MODULE & REACTION WHEELS		1144	519
- SOLAR ARRAY/ROTATING BOOM DRIVE UNIT		2100	952
• PLATFORM	(18,361)		(8327)
- STRUCTURE		7421	3365
- PWR DISTRIBUTION		7194 ②	3263
- PROPULSION ORBIT KEEP MODULE (2)		436	198
- ORBIT KEEP MODULE SUPT STRUCT		265	120
- LOGISTIC DOCKING PORT (2)		640	290
- PROPULSION, ATTITUDE CONTROL MODULE (2)		1907	865
- ATTITUDE CONT MODULE SUPT STRUCT		375	170
- COMM-ANTENNA'S (KU-BAND & S-BAND)		123	56
• ROTATING BOOM	(15146)		(6869)
- STRUCTURE		4349	1972
- MANIPULATION & CARRIAGE		966	438
- TRAVELLER		143	65
- POWER DISTRIBUTION		9688	4394
• SOLAR ARRAY	(12,304)		(5458)
- STRUCTURE		593	269
- SOLAR BLANKET & DEPLOY MECH.		9634	4369
- POWER DISTRIBUTION		1746	792
- ACS, SUN SENSORS (2)		28	13
- TILT MECHANISM		33	15
TOTAL		53210	24131
20% CONTINGENCY		10642	4827
		63852	28958
CONSUMABLES		17938 ③	8135
		81790	37093
① INCLUDES 583 lbM POWER MODULE			
② INCLUDES 1818 lbM ORBIT KEEP BATTERIES & 452 lbM POWER REGULATION			
③ INCLUDES 6 MONTH SUPPLY OF ACS HYDRAZINE (16,700 lbM)			
6 MONTH SUPPLY OF ACS He (86 lbM)			
6 MONTH SUPPLY OF ORB KEEP ARGON (1152 lbM)			

Figure 3-2 Mass Summary

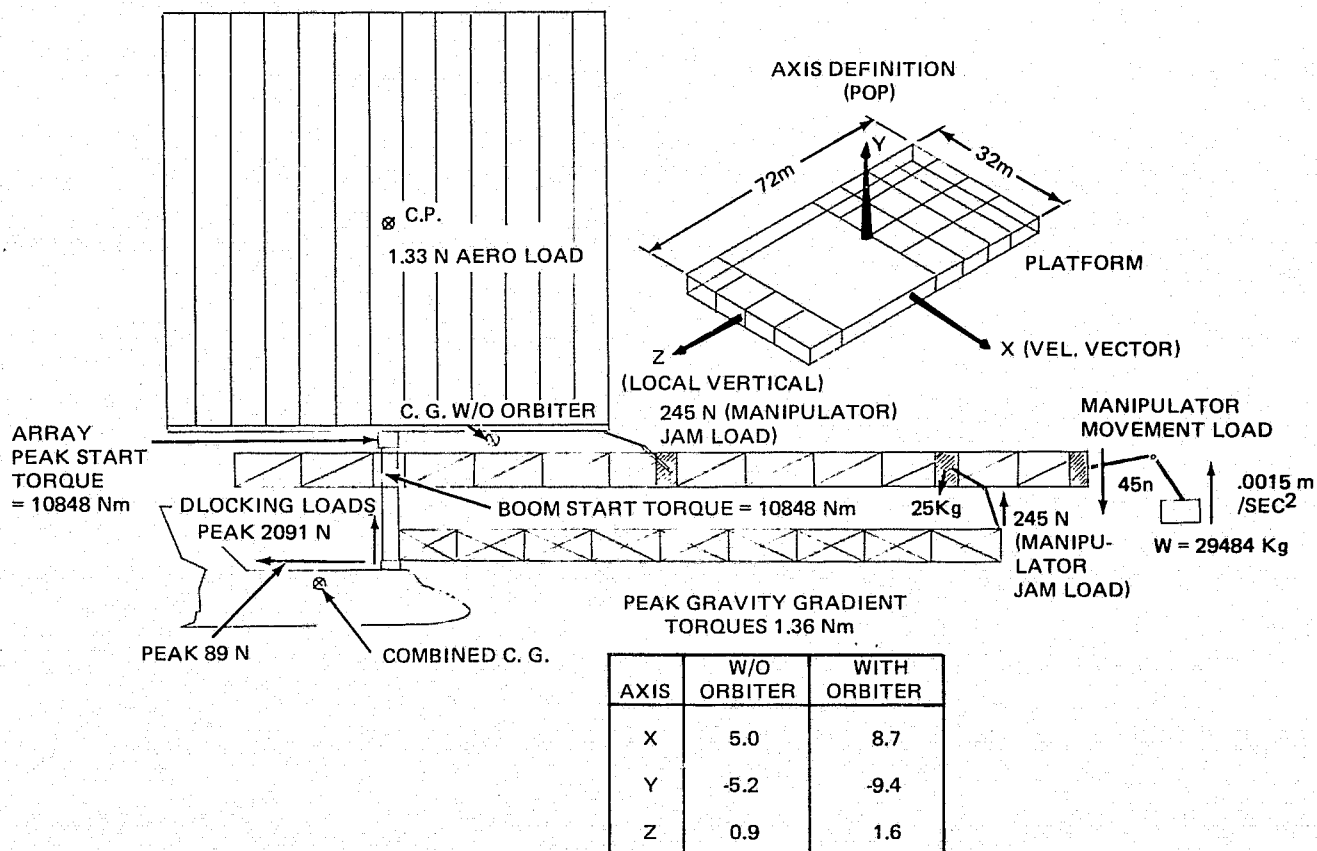
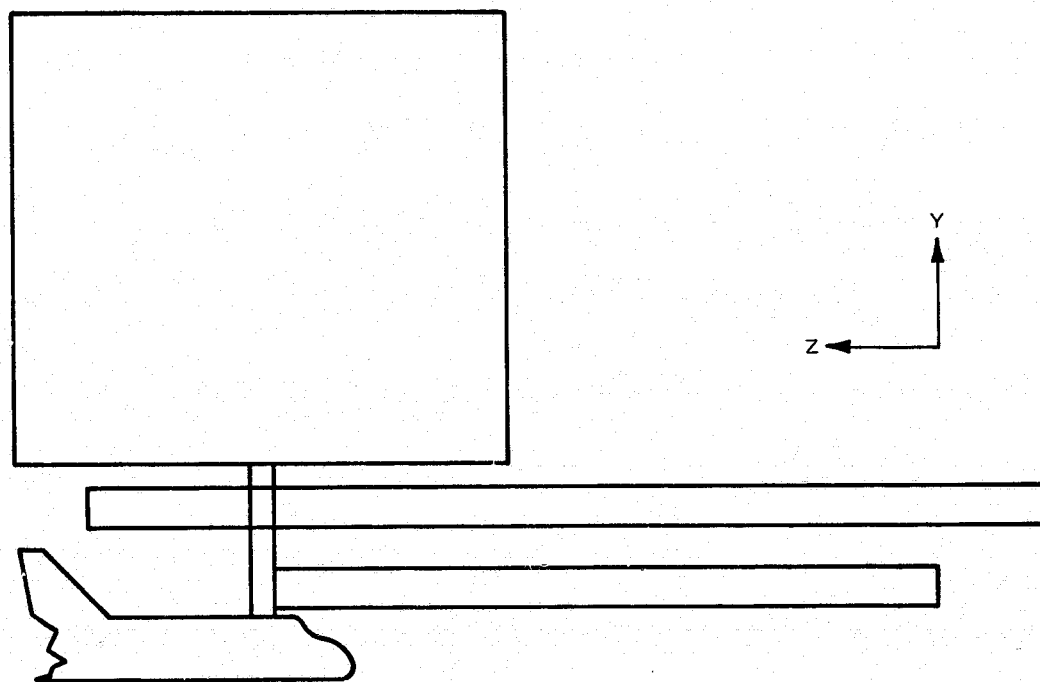


Figure 3-3 OCDA Structure Design Conditions



OCDA WEIGHT = 37100 Kg
SHUTTLE WEIGHT = 113400 Kg

CLOSING VELOCITY (Y) = .152 m/s
CLOSING VELOCITY (Z) = .030 m/s

ATTENUATOR = CONSTANT FORCE WITH 1 FT STROKE
MAXIMUM FORCE* (Y) = 213 Kg
(Z) = 9.07 Kg

*INCLUDES SAFETY FACTOR = 2

Figure 3-4 Preliminary Docking Loads, OCDA – Space Shuttle

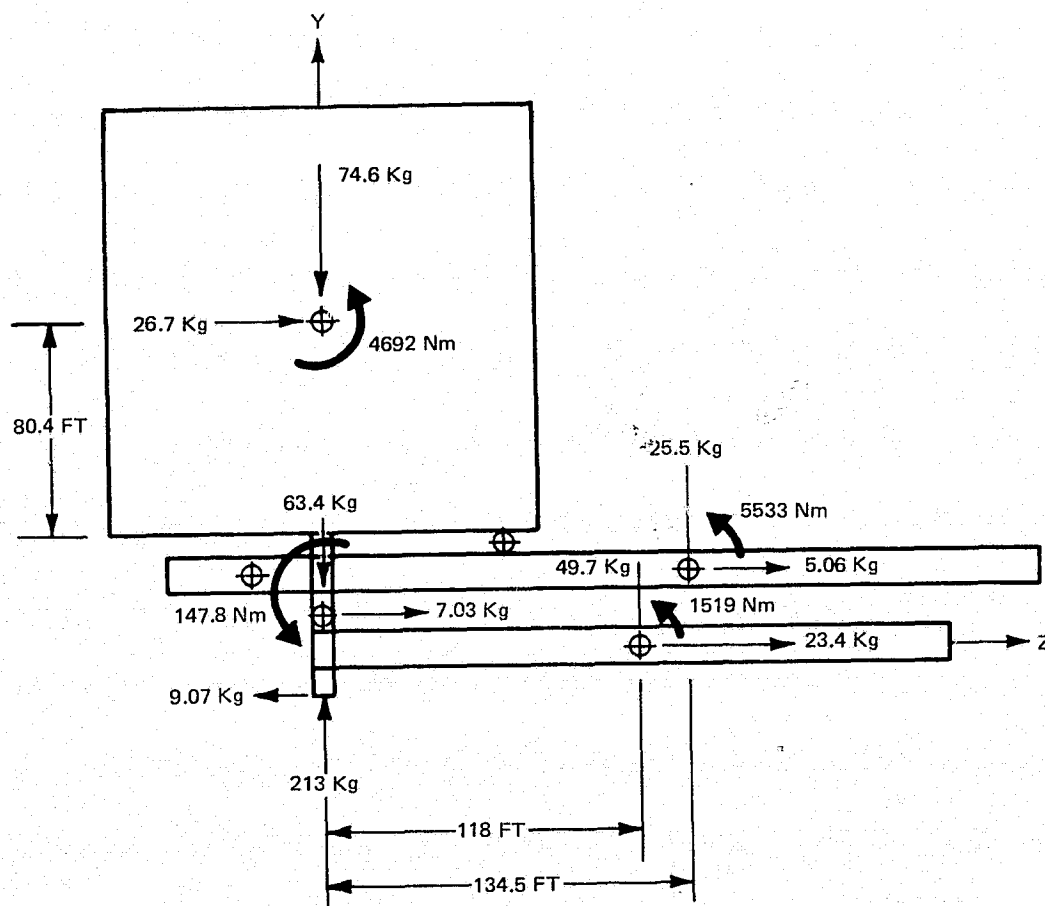


Figure 3-5 Limit Loads Due to Docking

ELEMENT	V_x (Kg)	V_y (Kg)	V_z (Kg)	M_x (Nm)	M_y (Nm)	M_z (Nm)
PLATFORM (0° BEAM)	-1.65	49.7	-23.4	- 3909 -10601	+325.9 + 884	+ 104
(180° BEAM)	-1.30 -1.18	77.7 70.6	-70.0 -63.5	- 8776 -23800	+141.6 + 384	+ 50.4 + 137
BEAM (0° BEAM)	-1.86 -1.78	25.5 28.1	- 5.31 - 5.85	- 4727 - 1743	881 325	1.972 .727
(180° BEAM)	-1.28 -1.16	35.8 39.5	- 2.48 - 2.73	15285 + 5636	626 + 231	2.582 .952
ARRAY (0° BEAM)	-4.34 -4.78 -5.00	75.6 82.2 54.8	26.67 29.4 2.38	- 1722 - 635 + 168	- 95.7 -112.8	1210 1421
(180° BEAM)	-5.52 -5.00	60.4	2.62		- 41.6	

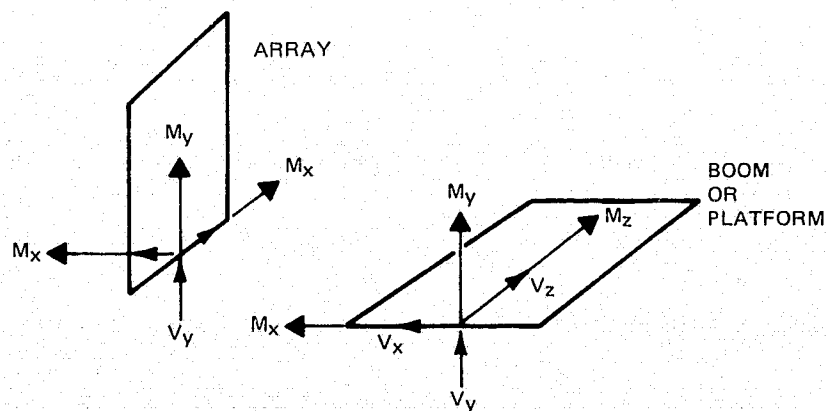
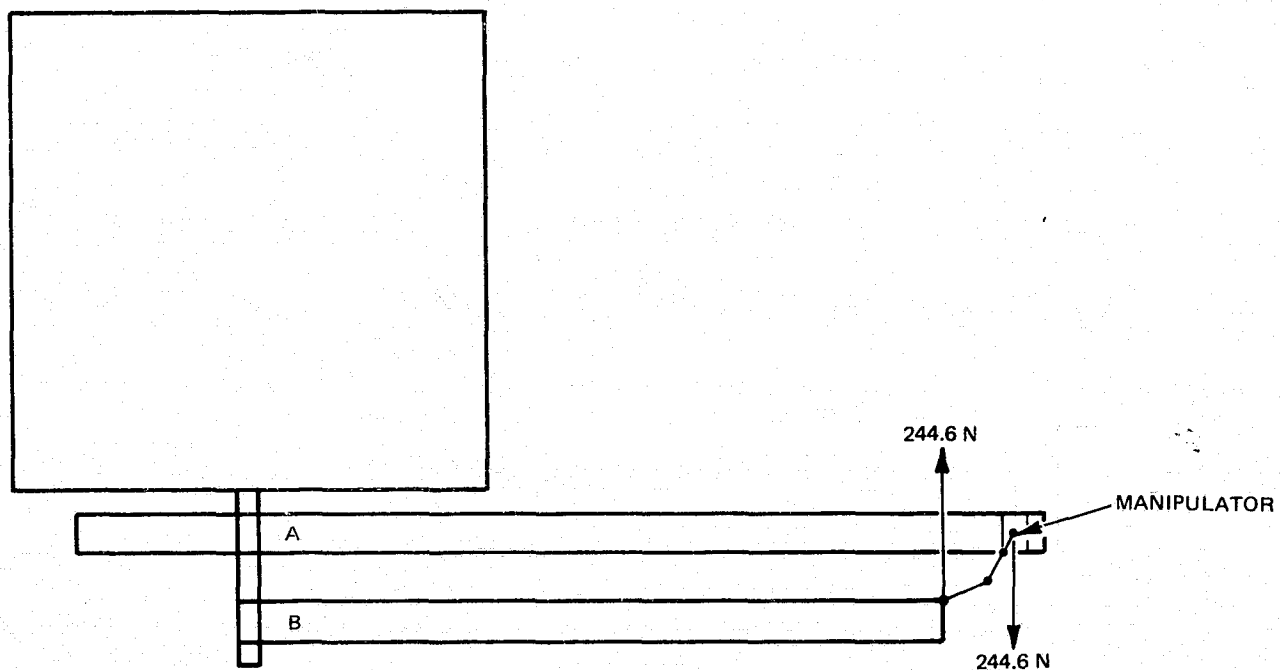


Figure 3-6 Support Reactions – OCDA Elements (Limit)



BENDING MOMENTS

- POINT A — BOOM — 20,069 Nm
- POINT B — PLATFORM — 17628 Nm

TORSION

- POINT B — PLATFORM — 3919 Nm (OUTB'D EDGE)

Figure 3-7 Design Conditions Due to Manipulator Loads

REQUIREMENT	RATIONALE/SOURCE
3.2.5.2 With any credible combination of a subsystem inactivated as a result of an accident and a portion of a redundant or backup system inoperative.	
3.2.6 For those malfunctions which may result in time-critical emergencies, provisions shall be made for:	B/2.4/32 (M)
3.2.6.1 The automatic switching to a safe mode.	
3.2.6.2 Caution and warning aboard the orbiter when tended to the OCDA.	
3.2.6.3 Caution and warning to the ground when the OCDA is unattended.	
3.2.7 Provision for command override of critical functions by the orbiter crew shall be provided during OCDA operation.	H/3.1.9/3.1-1
3.2.8 A pressure relief capability shall be provided for the OCDA tanks (e.g., propellant tanks) which automatically limits the maximum pressure.	H/3.1.13/3.1-2
3.2.9 A venting capability shall be provided for OCDA tanks for safely venting unused residuals during retrieval operations.	
3.2.10 RF communication capability shall be available between the Orbiter and the OCDA for command and control functions.	H/3.1.17/3.1-2
3.2.11 The critical command and control circuitry shall be designed to a fail-operational/failsafe as a minimum.	H/3.1.18/3.1-2
3.2.12 Conservative factors of safety shall be provided where critical single failure point modes of operation cannot be eliminated (pressure vessels, pressure lines, valves, etc.)	B/2.9/36

REQUIREMENT	RATIONALE/SOURCE
3.3 <u>Reliability:</u> 3.3.1 The mission success reliability goal for the OCDA shall be 0.97 minimum for all missions. Redundancy levels will be selected and defined to meet this criterion for all missions. 3.3.2 The OCDA shall be capable of operating with all critical functions performed within specified values following one component failure or any portion of a subsystem inactive for maintenance. This condition shall continue until maintenance can be performed. 3.3.3 Subsystem or component failures shall not propagate sequentially. As a minimum, equipment shall be designed to be fail-operational/failsafe. 3.3.4 All critical life limited components and subsystems shall be designed to allow in-orbit inspection. 3.3.5 Equipment or material sensitive to contamination shall be handled in a controlled environment. Fluids and materials shall be compatible with the combined environment in which they are used. 3.3.6 Loss of redundancy for OCDA critical functions shall be automatically detectable by the orbiter caution and warning. 3.3.7 Redundant paths shall be located so that an event which damages one path is not likely to damage the other.	H/3.2.1/3.2-1 B/2.1/35 B/2.4/35 B/2.5/35 B/2.6/35 B/2.7/35 (MOD) B/2.8/36
3.4 <u>Maintainability</u> 3.4.1 The OCDA shall be designed to provide access to equipment interfaces, equipment installations and service umbilicals requiring inspection, servicing, or verification.	I/3.5.2.3.3/3-106 (MOD.)

REQUIREMENT	RATIONALE/SOURCE
3.4.2 The OCDA shall be capable of having planned maintenance performed within TBD turnaround. The flight subsystems and their removable modules shall be located and access provided to allow removal and replacement as specified in Section 3.4.3.	I/3.5.2.2.2/3-105 (MOD.)
3.4.3 The OCDA flight subsystems and their replacement modules shall be designed such that they are accessible and capable of being removed and installed within TBD turnaround time. The times to remove and replace the various modules shall be identified and shall be demonstratable.	I/3.5.2.2/3-105 (MOD.)
3.4.4 The OCDA flight subsystems shall be capable of checkout, alignment (if required), connection, inspection and verification of electrical, fluid and mechanical interfaces during OCDA operations.	I/3.5.2.2.2/3-105 (MOD.)
3.5 <u>Electromagnetic Capability</u>: The OCDA system shall be designed to the compatibility requirements of MIL-STD-461 and MIL-STD-462 to assure that:	
3.5.1 The OCDA operations shall not be limited by electromagnetic interactions due to the electromagnetic emissions and susceptibilities of its subsystems.	
3.5.2 The OCDA shall not be a source of interference to or a victim of interference from nearby electrical and electronic equipments and systems.	
3.6 <u>OCDA/Shuttle Interfaces</u>	
3.6.1 <u>EPS</u>	
3.6.1.1 The OCDA shall provide the Shuttle while docked 20 kw ave of continuous electrical power for Shuttle operation.	

REQUIREMENT	RATIONALE/SOURCE
3.6.1.2 The OCDA shall provide circuit protection to electrically isolate the OCDA from the Shuttle in the event of an electrical failure or out-of-tolerance condition. The circuit protection shall be designed to preclude OCDA wire damage. 3.6.2 <u>Avionics</u>: The avionics functional requirements and interfaces between the Shuttle, OCDA and the ground are defined in Table 3-1. 3.6.3 <u>Docking, Berthing and Transfer</u> 3.6.3.1 The Shuttle shall be the active element in all Shuttle/OCDA rendezvous and docking operations. The OCDA shall be the cooperative target. 3.6.3.2 The OCDA docking interface shall be consistent with the Shuttle supplied (payload chargeable) docking module. 3.6.3.3 Crew and logistics transfer (i.e., logistics located in the Shuttle cabin) shall be EVA through the docking module. 3.6.3.4 The OCDA shall provide hand rails, hand grips, foot restraints, tethers, tiedowns and other transfer mechanisms to assist EVA transfer of crew and logistics between the Shuttle and the OCDA. 3.6.3.5 The OCDA shall provide two berthing ports to accommodate Shuttle payload bay compatible modules. The berthing ports shall be located within the Shuttle RMS reach envelope when the Shuttle is docked to the OCDA. 3.6.3.6 The OCDA boom manipulator shall have the capability to receive a hand over from the Shuttle RMS when the Shuttle is docked to the OCDA.	

Table 3-1 OCDA/Shuttle and OCDA/Ground Avionics Interfaces

INTERFACE AVIONIC FUNCTIONAL REQUIREMENTS	DIRECT OR VIA TDRS				HARDLINE		RF LINK	
	OCDA TO GROUND VIA SHUTTLE	GROUND TO OCDA VIA SHUTTLE	AUTONOMOUS OCDA TO GROUND	GROUND TO AUTONOMOUS OCDA	SHUTTLE TO ATTACHED OCDA	ATTACHED OCDA TO SHUTTLE	SHUTTLE TO AUTONOMOUS OCDA	AUTONOMOUS OCDA TO SHUTTLE
SCIENTIFIC DATA	X		X			X		X
ENGINEERING DATA	X		X			X		X
EVA AUDIO	X	X			X	X		
TELEVISION	X		X			X		X
COMMAND		X		X	X		X	
GN&C (UPDATE)		X		X	X		X	
C&W	X		X			X		X
MASTER TIMING		X		X	X		X	
RENDEZVOUS							X	

REQUIREMENT	RATIONALE/SOURCE
3.7 <u>OCDA/Experiment Interface</u> 3.7.1 <u>EPS</u> 3.7.1.1 The OCDA shall provide electrical power to the experiments per Section 4.3.1. 3.7.1.2 Electrical connector hook-ups shall be simple push to lock operations. 3.7.1.3 "J" box attachment shall be a one step operation. 3.7.1.4 The OCDA shall provide circuit protection to electrically isolate the OCDA from the experiment in the event of an electrical failure or out-of-tolerance condition. The circuit protection shall be designed to preclude OCDA wire damage. 3.7.1.5 The experiment shall provide its own circuit protection to protect itself from electrical damage and wire damage. 3.7.1.6 Thermal control shall be the responsibility of the experiment. 3.7.2 <u>Avionics</u>: The avionics functional requirements and interfaces between the OCDA and the experiment are defined in Table 3-2. 3.7.3 <u>Mechanical</u> 3.7.3.1 The experiment shall provide attachment points which are consistent with: ● Boom manipulator end effector attachment mechanisms ● OCDA platform attachment mechanisms ● Boom traveler mechanisms.	

Table 3-2 OCDA/Experiment Avionic Interfaces

INTERFACE AVIONIC FUNCTIONAL REQUIREMENTS	HARDLINE	
	EXPERIMENT TO OCDA	OCDA TO EXPERIMENT
SCIENTIFIC DATA	X	
ENGINEERING DATA	X	
TELEVISION	X	
COMMAND		X
GN&C		X
C&W	X	
MASTER TIMING		X

REQUIREMENT	RATIONALE/SOURCE
3.7.3.2 The experiment shall provide the appropriate hand rails, hand grips, foot restraints, tether attachment points, tiedowns and other transfer mechanisms to assist an EVA crew in minimal equipment operation and maintenance. Normal equipment operation and maintenance shall be by boom manipulators. 3.7.3.3 The experiment attachment mechanisms shall be capable of being connected and disconnected by boom manipulator and EVA personnel without special tools. 3.7.3.4 The OCDA shall provide hand rails, hand grips, foot restraints, tethers, tiedowns and other transfer mechanisms to and from the experiment area. 3.7.3.5 Experiment alignment prism attachments shall be a one step operation.	

REQUIREMENT	RATIONALE/SOURCE
3.7.4 <u>Fluid</u> 3.7.4.1 The OCDA shall not initially provide any fluid interfaces. All experiment fluid systems shall be of a self-contained modular type. Provisions shall be made for subsequent cooling loops from an OCDA mounted radiator to the Shuttle. 3.7.4.2 The experiment venting system shall be designed to preclude propulsive thrusting when venting. 3.7.4.3 The experiment fluid systems shall be designed so that expulsion of materials, e.g., gases and fluids, shall not impinge on OCDA or neighboring experiment structures.	

Section 4
SUBSYSTEM REQUIREMENTS

REQUIREMENT	RATIONALE/SOURCE
4.1 Structure 4.1.1 All major load-carrying structures of the structural subsystems shall be designed to a safe life of a minimum ten years in orbit. Life limitations shall be identified. 4.1.2 As a goal, failsafe design concepts shall be applied to all critical structure so that failure of a single structural member shall not degrade the strength of stiffness of the structure to the extent that the crew is in immediate jeopardy. 4.1.3 The structure shall be designed to resist damage resulting from accidental impact during crew activities. 4.1.4 Safety factors used for structural design shall be consistent with those currently used for manned operations. 4.1.4.1 <u>Strength</u> 4.1.4.1.1 Ultimate Strength: A factor of safety of 1.5 shall be applied to the ultimate strength for unpressurized structure. 4.1.4.1.2 Yield Strength: A factor of 1.1 shall be applied to the yield strength for unpressurized structure and 1.5 for pressurized structure. 4.1.4.2 Fail Safe Structure: The structure shall be designed so that a credible failure mode in the structure shall not result in catastrophic failure.	B/9.01/12 B/9.02/12 B/9.03/12 B/9.05/12

REQUIREMENT	RATIONALE/SOURCE
4.1.5 Meteoroid protection shall be provided by the OCDA design consistent with the meteoroid flux given in TM X-53865, second edition, dated August 1970. The design goal will be to provide sufficient protection to assure an 0.995 probability of no mission failure resulting from meteoroid penetration.	B/9.06/13
4.1.6 Orbital operations requiring orbiter manual docking or manual docking capability shall use the following design criteria: ● Axial closing velocity 0.152 m/sec ● Lateral velocity 0.030 m/sec ● Pitch, yaw and roll misalignment $\pm 5.0^\circ$ ● Radial miss distance 0.152 m (safety factor of 2.)	B/9.07/13
4.1.7 Dynamic isolation is required for rotating machinery.	B/9.08/13
4.1.8 Any gases vented overboard shall not directly impinge on OCDA structures or sensors.	B/9.09/13
4.1.9 Provisions shall be made for dissipation of waste heat generated during OCDA operation.	B/9.10/13
4.1.10 Structures shall be designed to withstand temperature cycling between -433°K to 366°K.	K/3.3.2/15
4.2 <u>Communications and Data Handling (C&DH)</u>	
4.2.1 The C&DH subsystem shall be designed to provide communications with the NASA STDN/TDRSS, the orbiter and other cooperating vehicles.	B/14.01/19
4.2.2 The communications section shall provide the following capability: 4.2.2.1 Reception, transmission, processing, and distribution of multiple duplex voice channels.	B/14.02/19

REQUIREMENT	RATIONALE/SOURCE
4.2.2.2 Generation, processing, distribution and transmission of television signals. 4.2.2.3 Transmission of operational PCM telemetry and wideband experiment data. 4.2.2.4 Reception and processing of commands. 4.2.2.5 Transmission of commands to experiments and remote manipulator. 4.2.2.6 Reception of experiments PCM telemetry. 4.2.2.7 Transmission and reception of EVA voice and data.	
4.2.3 The normal uplink and downlink channels shall operate between the STDN and the OCDA at Ku-band and S-band frequencies through the TDRSS. The communication links between the OCDA and the orbiter shall operate at S-band frequencies; the links between the OCDA and the experiments shall be S-band.	B/14.03/19
4.2.4 The capability for voice conference shall be provided between the orbiter the ground network and the OCDA; and between the OCDA and ground network during periods of EVA activity.	B/14.04/19
4.2.5 Closed circuit tv shall be provided for support of special area monitoring.	B/14/07/20
4.2.6 OCDA attitude constraints shall not be required to maintain acceptable communications.	B/14.08/20
4.2.7 A capability for RF or hardline communications with EVA crewmen will be provided.	B/14.09/20
4.2.8 The data handling section shall be compatible with all OCDA modules, mission hardware, orbiter, and the STDN/TDRSS communication systems.	B/15.01/21

REQUIREMENT	RATIONALE/SOURCE
4.2.9 System and mission status information shall be available on board for transmission to the ground as required. This information will be available both real time and stored.	B/15.02/21
4.2.10 The DH section shall provide the following functions: ● Data recording management ● Telemetry format selection ● Subsystem measurements and configuration management ● Mission hardware support ● Data processing management ● Command control.	B/15.03/21
4.2.10.1 Data Recording Management: The DH section shall provide control for operating temporary and permanent recorders.	B/14.04/21
4.2.10.2 Telemetry Format Section: The onboard computers shall provide: 4.2.10.2.1 The capability to load programmable PCM data formats. 4.2.10.2.2 The capability to select fixed or programmable formats.	B/15.05/21
4.2.10.3 Subsystem Measurements and Configuration Management: The DH shall provide: 4.2.10.3.1 Subsystem measurement data and system configuration on request for CRT display in the orbiter. 4.2.10.3.2 Scaling, conversion and formatting for display in orbiter. 4.2.10.3.3 Out-of-tolerance identification and corrective action recommendation.	B/15.06/21
4.2.10.4 Mission Hardware Support: The DH shall provide the capability to monitor experiment subsystem health status. The interface between these subsystems shall be PCM data stream obtained from hardline or	B/15.10/22

REQUIREMENT	RATIONALE/SOURCE
RF communication links. Accommodation of variable data rates and formats, to the extent that these may be changed for each experiment, shall be provided.	
4.2.10.5 The DH shall have the capability to transmit commands to all OCDA subsystems and mission hardware and receive confirmation.	B/15.11/22
4.2.10.6 The OCDA shall have the capability to receive, store and transfer commands from the ground or orbiter to the OCDA subsystems and to mission hardware.	B/15.12/22
4.3 Electrical Power	
4.3.1 Electrical power during light-side operation shall be provided by add-on solar array modules sized to provide the following average power at slip ring:	C/3.0/3-4
4.3.1.1 Housekeeping and orbitkeeping power 33.9 kw power	C/4.0/4-6
4.3.1.2 Shuttle Support Power: 35.6 kw	D/SUMMARY/1
4.3.1.3 Experiment Power: Dictated by the individual experiments, examples of which are shown in Table 4-1.	

Table 4-1 Experiment Power Requirements

EXPERIMENT	POWER AT SLIP RING, KW
ANTENNA CONSTRUCTION	73.7
LINEAR ARRAY-KLYSTRON	313
SQUARE ARRAY-KLYSTRON	300
LINEAR ARRAY-AMPLYTRON	134.4
STRUCTURAL FABRICATION	62.6

REQUIREMENT	RATIONALE/SOURCE
4.3.2 Electrical power during dark-side operation shall be provided by batteries whose energy is restored by solar array power during light side operation.	B/12.06/17(M)
4.3.3 The EPS shall accommodate the capability for growth including both configuration and electrical compatibility.	B/12.04/17
4.3.4 The EPS shall have a maintained lifetime of not less than 10 years.	B/12.05/17
4.3.4.1 Elements may be replaced in total or in modular form for maintenance or for growth up-rating.	
4.3.4.2 The required electrical power levels will be sustained without interruption during the maintenance or up-rating period.	
4.3.5 Standard EPS multimission module(s) shall be used for the housekeeping or orbit-keeping functions.	C/4.0/4-6
4.3.5.1 The multimission module shall be compatible with the Solar Array.	D/FIGURE 2/5
4.3.5.2 The multimission module shall interface with and accept 28 vdc from the orbiter/payload fuel cells.	D/FIGURE 2/5
4.3.5.3 The multimission module batteries shall be capable of being charged by the solar array during lightside operations and shall supply 28 vdc for housekeeping/orbit-keeping and Shuttle support during dark-side operation.	B/12.06/17 (M)
4.3.5.4 The housekeeping/orbit-keeping bus shall provide 28 vdc distribution to housekeeping/orbit-keeping power equipment.	D/Fig. 4/7
4.3.5.5 The distribution system shall provide circuit protection devices for all power equipment and OCDA distribution wiring.	B/13.01/18

REQUIREMENT	RATIONALE/SOURCE
4.3.6 The platform bus shall: 4.3.6.1 Interface with and accept 200 vdc transmission from the solar array. 4.3.6.2 The 200 vdc distribution bus shall provide at least one interface compatible with amplatron and klystron dc to dc conversion hardware. 4.3.6.3 Provide 200 vdc distribution to platform activities such as construction, boom and experiment operation and lights. 4.3.7 The platform electrical power distribution section shall provide circuit protection devices for all power equipment and OCDA distribution wiring. 4.3.8 The platform electrical power batteries shall be capable of being charged by the solar array during light-side operation and shall supply 200 vdc to the platform bus during dark-side operation.	D/FIGURE 2/5 D/FIG. 4/7 B/13.01/18 B/12.06/17 (M)
4.4 <u>Attitude Control and Orbit-Keeping</u> 4.4.1 The OCDA shall maintain a continuous orbital ephemeris fix through an on-board program using periodic update. Completely autonomous navigation is not required. 4.4.2 The OCDA shall provide means for producing control torques which are capable of meeting stabilization and control requirements for all modes of orbital operations including docked operations with an active or quiescent orbiter. 4.4.3 The OCDA shall provide orientation control for any combination of module configuration to accomodate attached mission hardware accuracy and orbit-keeping requirements.	B/17.01/24 (M) B/17.03/24 (M) B/17.04/24 (M)

REQUIREMENT	RATIONALE/SOURCE
4.4.4 Stabilization and control will be provided by the OCDA during construction and/or assembly of large structures.	B/17.06/24 (M)
4.4.5 Pointing and stability requirements for mission hardware which are in excess of those required for normal OCDA operations shall be provided by separate mission hardware stabilization and control.	B/17.07/24 (M)
4.4.6 The capability of maintaining dynamic stability when moving large masses relative to one another is required.	B/17.08/24 (M)
4.4.7 The OCDA must be stabilized to within TBD during docking operations with the shuttle transport system.	
4.4.8 The OCDA is a cooperative target during docking operations.	
4.5 <u>Thermal Control</u>	
4.5.1 The thermal control subsystem shall provide TBD operating temperature for all OCDA subsystems requiring thermal conditioning. The subsystem shall not require selective orientation in orbit to maintain its thermal control function.	H/4.2.1/4.2-1
4.5.2 The thermal control subsystem shall not provide thermal control for any payload system.	H/4.2.2/4.2-1
4.5.3 A passive thermal control approach should be utilized where appropriate, or if not feasible, the design should minimize system complexity and weight.	H/4.2.3/4.2-1
4.6 <u>Platform Logistics and Assembly Subsystem</u>	
4.6.1 <u>Logistics Transfer</u>	
4.6.1.1 The logistics transfer shall provide the capability to:	
4.6.1.1.1 Transfer personnel and material to and from all OCDA assembly sites.	L/3.5.5/3-28

REQUIREMENT	RATIONALE/SOURCE
● Decleration rate 0 to 0.002 m/sec² (289120 N load) 0 to 0.31 m/sec² (no load) ● Reach distance 12 m (approx.) ● Reach angle Limited only by interference with orbiter structure ● Tip position accuracy 5 cm ● Orientation accuracy ±0.1° ● Tip force 44.5 N to 89 N ● Tip deflection 0.1 in/lb tip force ● Force feedback 1.8 kg - 2.3 kg ● Visibility direct or tv combination	
4.6.1.2.1.2 The boom manipulator shall incorporate an automatic joint lock in case of joint motor failure.	N/Table 3-1/68
4.6.1.2.1.3 The boom manipulator shall be operated from the Shuttle payload handling station.	L/3.4.1.4/3-20
4.6.1.2.1.4 Collision avoidance software and/or max torque override for the manipulator shall be provided by the Shuttle.	N/Table 3-1/
4.6.1.2.2 Traveler: The traveler shall have the capability to transport the boom manipulator, men and materials along the boom to the desired work site.	L/3.4.1.4/3-20

REQUIREMENT	RATIONALE/SOURCE
4.6.1.2.2.1 The traveler shall be mounted on two boom rails and moved by an electric traction drive acting against the lower rail. Power to propel the traveler shall be supplied by a power pick-up rail mounted on the boom structure.	L/3.4.1.4/3-20
4.6.1.2.2.2 The traveler shall have the following characteristics: ● Translation velocity 0 to 0.06 m/sec (289120 N load) 0 to 0.6 m/sec (no load) ● Acceleration Rate 0 to 0.002 m/sec² (289120 N load) 0 to 0.15 m/sec² (no load) ● Deceleration Rate 0 to 0.002 m/sec² (289120 N load) 0 to 0.15 m/sec² (no load) ● Position Accuracy 10 cm ● Visibility Direct or tv combination.	
4.6.1.2.2.3 Traveler operation shall be controlled from three different locations: ● The Shuttle payload handling station ● The traveler ● The OCDA core module.	

REQUIREMENT	RATIONALE/SOURCE
4.6.1.2.2.4 Traveler control from the above three locations shall be on a first come, first serve basis. In the event of simultaneous requests for control, the following order of priority shall prevail: 1. The traveler 2. The OCDA core module 3. The Shuttle payload handling station. 4.6.1.2.3 Boom/Solar Array Drive Unit: The drive unit shall be mounted on the OCDA mast structure. The unit shall provide two coaxial driving mechanisms to move the rotating boom and drive the solar array. The unit is to operate in low earth orbit with an expected life of 10 years. 4.6.1.2.3.1 Boom/Solar Array Drive Unit: The unit shall meet the following operating requirements: ● Boom drive - Structural strength sufficient to support a static bending moment of 18035 Nm. - Develop an operating torque of 1627 Nm with provision for a torque limiting slip clutch. - Provide a no-load rotation rate of 180°/min for a total angular travel of $\pm 720^\circ$. - Provide for electrical power transfer from the OCDA platform to boom, power level and voltage TBD.	L/3.4.1.2/3-19

REQUIREMENT	RATIONALE/SOURCE
● Solar Array Drive - Structural strength sufficient to support a static bending moment of 18035 Nm. - Operate at an orbital period of 90 min. with provision for a higher speed tracking mode. (Array inertia-842,248 Kg m². - Transfer power from the solar array to the platform utilizing a slip ring assembly (250 kw at 200 V). ● Beam size 4 m Sq. x 108 m long ● Beam mass 9385 kg ● Rotation velocity TBD ● Acceleration rate TBD ● Deceleration rate TBD ● Position accuracy ±0.6 m ● Visibility Direct of tv combination 4.6.1.2.3.2 Boom drive unit operation shall be controlled from three different locations: ● The Shuttle payload handling station ● The traveler ● The OCDA Core.	G/2.1/7 L/Figure 1-5/1-6

REQUIREMENT	RATIONALE/SOURCE
4.6.1.2.3.3 Boom drive unit control from the above three locations shall be on a first come, first serve basis. In the event of simultaneous requests for control, the following order of priority shall prevail: 1. The traveler 2. The OCDA Core 3. The Shuttle payload handling station.	
4.6.2 <u>Payload Logistics Assembly Fixtures:</u> A payload bay assembly fixture shall be designed to minimize OCDA platform element assembly time and to insure dimensional repeatability.	L/3.4.3/3-21
4.6.2.1 The fixture shall be constructed of composite materials to minimize dimensional changes and sized to assemble both 8 m x 8 m x 4 m and 4 m x 4 m x 8 m modular subassemblies consisting of beams, tubular posts and tension rods.	L/3.4.3/3-21
4.6.2.2 The fixture shall be designed for transportation to and from orbit in a disassembled configuration in the Shuttle payload bay.	L/3.4.3/3-21
4.6.2.3 The fixture shall be designed for assembly and disassembly with the Shuttle RMS and for attachment to the Shuttle payload bay longeron attach points.	L/3.4.3/3-21
4.6.2.4 The fixture shall be designed to provide easy removal of the assembled platform element with the Shuttle RMS.	L/3.4.3/3-21

REQUIREMENT	RATIONALE/SOURCE
4.7 <u>Illumination</u> 4.7.1 <u>Orbiter Rendezvous Tracking Light:</u> A high intensity flashing light shall be provided for visual acquisition and tracking during rendezvous. 4.7.1.1 A single light (plus redundancy) shall be mounted on the earth facing end of the OCDA platform. 4.7.1.2 The tracking light shall provide a point source of light of 140 beam candlepower seconds minimum intensity at a visual range of 74 km. 4.7.2 <u>Orientation Lights:</u> Position lights shall be mounted on the exterior perimeter to provide visual cues for determining vehicle orientation. 4.7.2.1 Lights (plus redundancy) shall be mounted on each corner of the OCDA platform, on two corners of the solar array side away from the platform and on the end of the long boom. 4.7.2.2 Each light shall a luminous intensity of 2.5 candlepower. 4.7.3 <u>Docking Target:</u> An illuminated three dimensional target shall be provided where visual alignment information is required for docking maneuvers. Minimum brightness shall be 0.2 ft-candles. 4.7.4 <u>Orbiter Payload Bay:</u> Illumination shall be provided to permit material unloading from the orbiter payload bay. Minimum brightness shall be 5 ft-candles of illumination at the center of the bay. 4.7.5 <u>Boom Traveler:</u> Illumination shall be provided to permit material to be loaded on the traveler.	E/REQM'TS/1 E/REQM'TS/1 E/REQM'TS/2 E/REQM'TS/2 E/REQM'TS/2

REQUIREMENT	RATIONALE/SOURCE
4.7.5.1 A movable floodlight shall be mounted on the end of the OCDA platform adjacent to the orbiter payload bay.	
4.7.5.2 The floodlight shall provide 3.5 ft-candles of illumination on the boom traveler when positioned on the short end of the boom.	
4.7.6 <u>Transfer Routes</u> : Illumination shall be available on the OCDA structure or along the boom to provide a pathway of light between the work site and orbiter. Minimum brightness along the transfer route shall be 1 ft-candle.	E/REQM'TS/2
4.7.7 <u>Work Site</u> : The work site shall be illuminated with a minimum of 10 ft-candles to permit efficient crew and RMS operation.	E/REQM'TS/2
4.7.8 <u>Remote Manipulator System</u> : A light shall be mounted on the RMS; it shall provide a 50 ft-candle minimum intensity on an OCDA operation at a distance of 3 m from the light.	E/REQM'TS/3
4.8 <u>Propulsion</u>	
4.8.1 The propulsion subsystem shall be designed to provide control forces capable of meeting three axis attitude hold, attitude maneuvers, and translation requirements during all phases of OCDS assembly and operations, including operations with the orbiter. The control torque requirements shall be in accordance with Figure 4-1.	B/21.01/30 C/2.0/2-2
4.8.2 The propulsion subsystem shall provide control forces to maintain OCDA orbit to within TBD altitude and TBD inclination. The thrust and propellant requirements are in accordance with Figure 4-2.	C/2.0/2-3

	TORQUES (FT-LBS)									
	WITH ORBITER						WITHOUT ORBITER			
	T_x		T_y		T_z		T_x		T_y	
	BIAS	CYCLIC	BIAS	CYCLIC	BIAS	CYCLIC	BIAS	CYCLIC	BIAS	CYCLIC
AERODYNAMIC	0	0	- 5.5	+4.8	21.5	+20.2	-0	0	8.5	± 8.7
GRAVITY GRADIENT	9.0	±5.6	- 8.0	+1.6	1.5	± 0.5	-9.0	±3.5	-2.0	± 2.2
SOLAR PRESSURE	0	±0.4	0	0	0	± 0.4	0	±0.3	0	0
MAGNETIC (UNCOMP)	0.02	0	0	0	0.02	0	0.003	0	0	0
TOTALS	9.0	±6.0	-13.5	±6.4	23.0	±21.1	-9.0	±3.8	6.5	±10.9

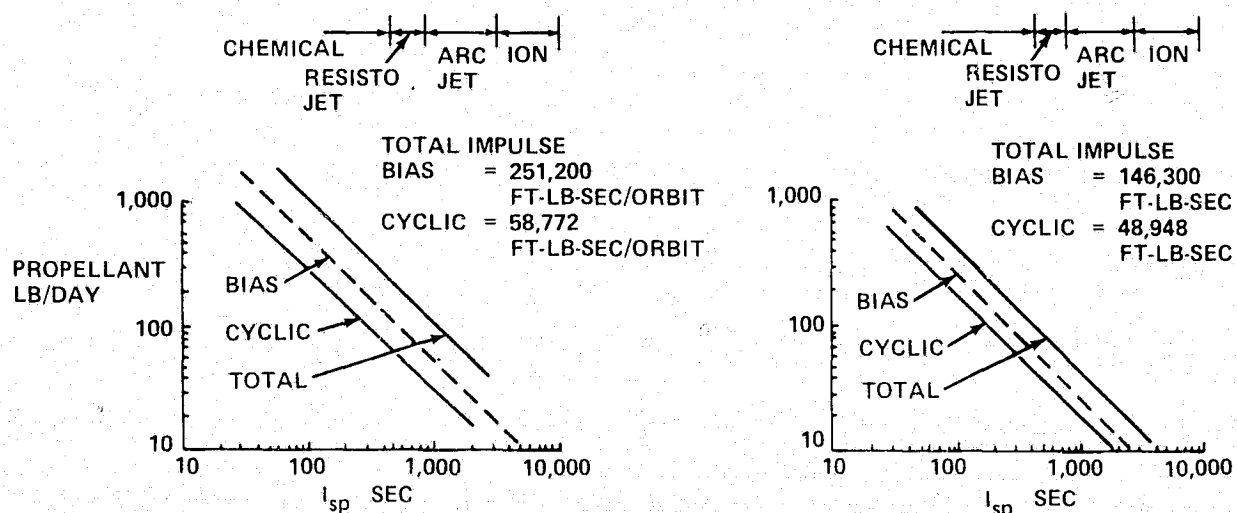


Figure 4-1 Control System Requirements

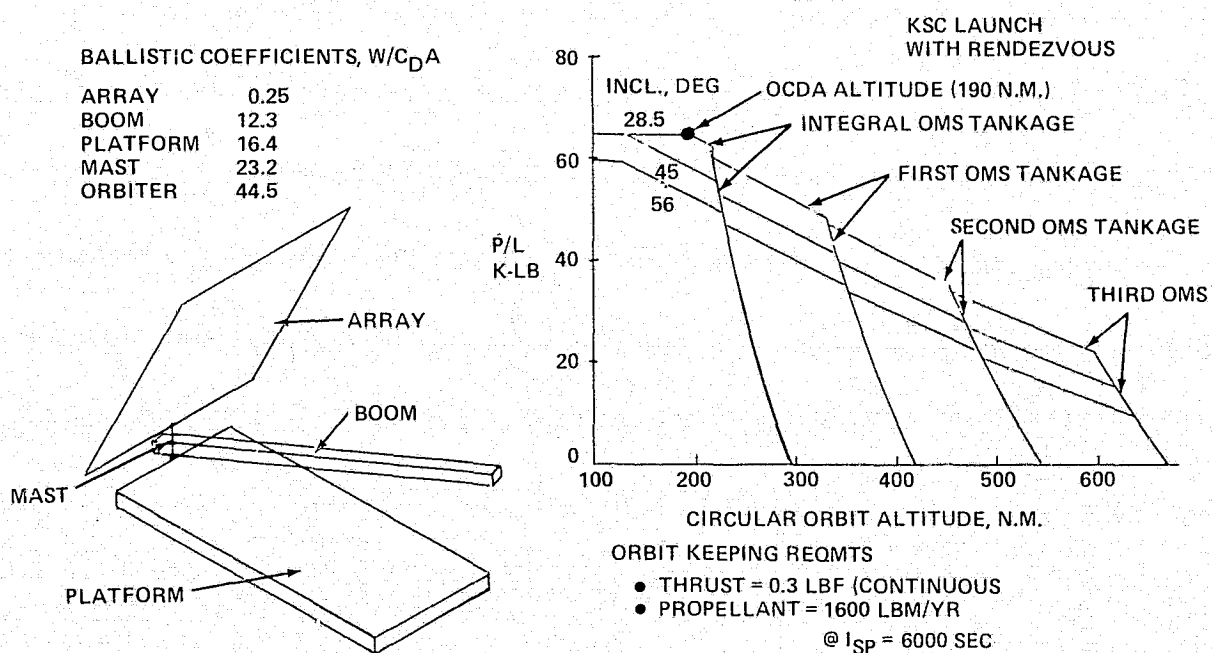


Figure 4-2 Orbit-Keeping Requirements

REQUIREMENT	RATIONALE/SOURCE
4.8.3 The propulsion subsystem shall be a modular LRU design consisting of: • Altitude control modules • Orbit-keeping Modules.	B/21.02/30 C/4.0/4-4
4.8.4 The propulsion subsystem tankage shall be sized for a six month propellant supply.	C/4.0/4-4
4.8.5 The propulsion thrusters shall be located in such a manner to provide minimum cross coupling effects.	B/21.03/30
4.8.6 The propulsion thrusters shall be located to minimize plume impingement effects on OCDA, mission hardware or orbiter structures.	B/21.04/30
4.8.7 The propulsion modules shall be capable of being launched and carried by the orbiter safely while fully loaded with propellants.	B/21.05/30
4.8.8 Thruster size shall reflect an optimum compromise between required attitude control authority, thruster state-of-the-art, redundancy, orbit-keeping requirement, and interaction with other altitude control devices.	B/21.08/30

Appendix A

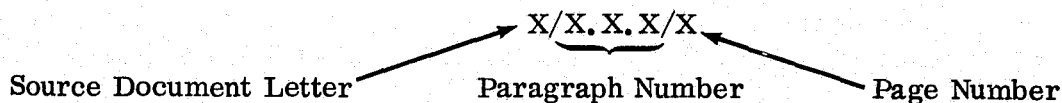
RATIONALE/SOURCE EXPLANATION AND LISTINGS

INTRODUCTION

The stated requirements which appear in the body of this document result from the Orbital Construction Demonstration Study under Contract NAS 9-14916, literature search and conversation with people in their recognized field of endeavor. References identifying the requirement source(s) are listed next to each requirement. The source code explanation is defined below along with the source documentation.

Source Explanation and Source Documentation

The Rationale/Source column to the right of the Requirements column documents the location of a specific requirement contained in existing documentation.



Source Document

- A. Orbital Assembly Demonstration Study, SOW, Exhibit A, dated 7 August 1975.
- B. Space Construction Base Design Guidelines and Criteria, JSC-11867, dated January 1977.
- C. Orbital Construction Demonstration Study, Contract NAS 9-14916, dated December 1976.
- D. IOM, "Feasibility Study of EPS for the OCDA," NSS-OC-M0019, dated 30 August 1976.
- E. IOM, "OCDA Illumination Requirements," NSS-OC-M0016, dated 26 July 1976.
- F. Orbital Construction Demonstration Study, Contract NAS 9-14916, dated September 1976.
- G. Orbital Construction Demonstration Study (8th Progress Note), NSS-OC-RP007, dated 5 October 1976.
- H. IOM, "Rug Requirements, Revision 2," B81M047-73054, dated 15 August 1973.
- I. Space Shuttle Flight and Ground System Specification, Level II Program Definition and Requirements, JSC 07700, Volume X, Revision B, dated 18 August, 1975.

- J. Discussions with Mr. A. Zimbalatti, Grumman Aerospace Corporation EMC Group Head.
- K. Solar Power Satellite, Analysis of Alternatives for Transporting Material to Geosynchronous Orbit, NASA Grant NGT 44-005-114, dated 15 October 1976.
- L. Orbital Construction Demonstration Study, Final Report, Contract NAS 9-14916, Report No. NSS-0C-RP-008, dated 1 December 1976.
- M. Application of EVA Guidelines and Design Criteria, Volume EVA Selection/Systems Design Considerations, NASA-CR-128926.
- N. Space Station Systems Analysis Study, Part 2 Final Report, Volume 3, Book 2, Contract No. NAS 9-14958.
- O. Space Shuttle System Payload Accommodations, Volume XIV, JSC 07700, Revision D, dated 26 November 1975.
- P. Space Station Systems Analysis Study Program Review, Volume 2, dated 19-20 April 1977, Contract No. NAS 8-31993, Report No. NSS-SS-RP016.
- Q. Space Shuttle System Summary, Rockwell International Space Division, dated July 1976, Report No. SS76-32.

Appendix B

This appendix contains a detailed listing of the technology objectives, the demonstration requirements and their demonstration need weight factor. These requirements are catalogued by the following technology disciplines:

- Structures
- Propulsion
- Solar Array
- Stabilization and Control
- Power Distribution
- Reflector Mission Facets
- Power Transmission
- Radiators
- Assembly Operations
- Thermal Cavities
- Mission OPS
- Large Mirror Surfaces.
- Processes

The demonstration need factors are based on the following rationale:

	DEMO NEED WGT.									
	1	2	3	4	5	6	7	8	9	10
TECHNOLOGY	FULLY DEVELOPED & SPACE QUAL'ED	PARTIALLY DEVELOPED & PLANNED FOR SPACE DEMO IN NEAR TERM	KNOWN BUT NOT DEVELOPED & WOULD BE AUGMENTED BY SPACE DEMO	NOT KNOWN BUT CHANCE OF BECOMING KNOWN GOOD IF SPACE DEMO USED	NOT KNOWN, SPACE DEMO MANDATORY TO FINDING SOLUTION					
HARDWARE	OFF-THE SHELF OR PROTOTYPE AVAILABLE WITH REQ'D FUNCTION & PERFORMANCE	FUNCTIONALLY EQUIVALENT HARDWARE AVAIL NEEDING MODIFICATION	FUNCTIONALLY EQ'V. HARDWARE BEING DEVELOPE. DEVELOPMENT NEEDING ORBIT VERIFICATION	NO HARDWARE IN USE — NEEDS SPACE DEMO DATA INPUT	HARDWARE NOT AVAILABLE UNLESS BREAK THROUGH ACHIEVED VIA SPACE DEMO					
GROUND TEST	CAN FULLY BE ANSWERED BY GROUND TEST	DESIRABLE TO HAVE GROUND TEST AUGMENTED WITH FLT TEST	HIGHLY DESIRABLE TO HAVE GROUND TEST AUGMENTED WITH FLT TEST	MANDATORY TO HAVE GROUND AUGMENTED WITH FLT TEST	ONLY FLIGHT TEST WILL GIVE ANSWER					

OCDA Structural Objectives

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
1a. Demonstrate Fabrication of Building Block Structure	1.1 Photovoltaic SPS Related	
	1.1.1 Fabricate 1 m deep beam to accuracy of 1 m/100 m (min length - TBD m)	6
	1.1.2 Fabricate 20 m deep beam to accuracy of 1 m/100 m (min length - TBD m)	7
	1.1.3 Fabricate 250 m deep beam to accuracy of 1m/100 m (min length - TBD m)	9
	1.2 MPTS Related	
	1.2.1 Fabricate 1 m deep beam to accuracy of 1 ARC min	6
	1.2.2 Test for outgassing at a temp of 440°K	5
	1.3 Solar Thermal SPS Related - Fabri- cate TBD-m deep beam to accuracy of 0.1° at a rate of TBD m/min (Min Length = TBD)	6
	1.4 Large Antenna Related - Fabricate TBD-m deep 50 m long parabolic shape beam to an accuracy of λ (λ = wavelength) at a rate of TBD m/min	6

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
1b. Demonstrate Deployable Building Block Structure	1.5 Photovoltaic SPS Related	
	1.5.1 Deploy end fitting for 1 m deep space fab beam and demonstrate that it is compatible with .1 m/100 m beam accuracy and 1.5 m/min productivity.	6
	1.5.2 Deploy end fitting for 20 m space fab beam and demonstrate compatibility with 1 m/100 m beam accuracy and .3 m/min productivity.	7
	1.5.3 Deploy end fitting for 250 m deep space fab beam and demonstrate producibility.	9
	1.5.4 Test integrated end fitting/ beam by	
	1.5.4.1 Axial loading to TBD	5
	1.5.4.2 Maintain 1 m/100 m accuracy with 393°K temp gradient between cap members	5
	1.6 MPTS Related	
	1.6.1 Deploy 20 m x 20 m Oct-Tet building block struct and demon- strate RMS flatness of $\lambda / 10$ (.012 m)	6

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
	1.6.2 Deploy 100 m x 100 m Oct-Tet building block struct and demonstrate RMS flatness of $\lambda / 10$ (.012 m)	8
	1.6.3 Test strength and accuracy of building block struct at a temperature of 440°K at center and 225°K at edge	6
	1.6.4 Test accuracy with a 5°K gradient between upper and lower surface	5
	1.7 Solar Thermal Related (TBD)	
	1.8 Large Antenna Related	
	1.8.1 Deploy 50 m long boom and demonstrate positioning of antenna feed to within TBD m	8
	1.8.2 Deploy 4 m (dia) Oct-Tet building block struct that contains all electronics for bootlace lens communications antenna to an RMS accuracy of $\lambda / 10$	6

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
2. Demonstrate and Qualify Joint Assembly Procedures	2.1 Photovoltaic SPS Related	
	2.1.1 Join 1 m deep beams to form 20 m deep beam using joints that can correct for space fab beam eccentricities	7
	2.1.2 Join 20 m deep beams to form 250 m deep beams using joints that can correct for eccentricities of elements	9
	2.2 MPTS Related	
	2.2.1 Join 20 m x 20 m Oct-Tet sections and maintain this accuracy of $\lambda/10$	7
	2.2.2 Join 100 m x 100 m Oct-Tet sections and maintain RMS accuracy of $\lambda/10$	8
	2.3 Solar Thermal Related (TBD)	
	2.4 Large Antenna Related	
	2.4.1 Join radials to central hub of parabolic radiometer and achieve a surface accuracy of $\lambda/50$	7
	2.4.2 Join 4 m (dia) Oct-Tet elements of comm antenna into 60 m (dia) unit to a RMS accuracy of $\lambda/10$	9

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
5. Demonstrate Installation of Secondary Structure	5.1 Photovoltaic SPS Related	
	5.1.1 Demonstrate installation of power bus support structure	6
	5.1.2 Demonstrate installation of control system support structure	6
	5.1.3 Demonstrate installation of solar blanket interface fixtures	5
	5.1.4 Demonstrate installation of reflector interface fixtures	5
	5.1.5 Demonstrate installation of avionics support fixtures	5
	5.2 MPTS Related	
	5.2.1 Demonstrate installation of power bus support fixtures	5
	5.2.2 Demonstrate installation of equipment support fixtures	5
	5.2.3 Demonstrate installation of subarray to structure	5
	5.2.4 Demonstrate assembly of RF subarray	8
	5.3 Solar Thermal Related	
	5.3.1 Demonstrate installation of mirror facet support fixtures	7

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
	5.3.2 Demonstrate installation of avionics support fixtures	5
	5.3.3 Demonstrate installation of control system support structure	6
	5.3.4 Demonstrate installation of radiator support structure	5
	5.3.5 Demonstrate installation of power bus support structure	5
	5.3.6 Demonstrate installation of cavity interface structure	6
	5.4 Large Antenna Related	
	5.4.1 Demonstrate installation of support fixture for radiometer rf mesh	6
	5.4.2 Demonstrate installation of support structure for avionics and power	5
	5.4.3 Demonstrate installation of antenna feed system	6
	6.1 Photovoltaic SPS Related	
6. Measure Productivity	6.1.1 Demonstrate 1 to 1.5 m/min production rate for fab of 1 m deep beam	5

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
	6.1.2 Demonstrate .6 to 1 m/min production rate for fabrication of 20 m deep beam 6.1.3 Demonstrate .3 to .6 m/min production rate for fabrication of 250 m deep beam 6.1.4 Demonstrate joining operations at a rate of TBD min/joint 6.1.5 Perform integrated fab operation at rate of .3 m/min Including: ● Fabrication of structure ● Installation of bus system ● Installation of blankets ● Installation of reflectors ● Installation of subsystems ● Rotary joint installation 6.2 6.2.1 Demonstrate fab/or deployment and alignment of structure at rate of TBD kg/m-hr 6.2.2 Demonstrate assembly of rf subarrays at rate of TBD kg/m-hr	7 6 9 9

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
	6.2.3 Demonstrate integrated assembly of MPTS antenna at rate of TBD kg/m-hr including: • Structure assembly • Bus system installation • Astrionics installation • RF subarray assembly	9
	6.3 Solar Thermal Related	
	6.3.1 Demonstrate assembly of primary and secondary structure at rate of TBD kg/m-hr	7
	6.3.2 Demonstrate integrated assembly including at TBD kg/m-hr • Structural assembly • Mirror installation • Bus system installation • Radiator attachment • Rotary joint installation • Cavity installation	9
	6.4 Large Antenna Related	
	6.4.1 Demonstrate structural assembly at rate of TBD kg/m-hr	6

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
	6.4.2 Demonstrate integrated assembly at rate of TBD kg/m-hr including: • Structural assembly • Other (TBD)	9
7. Demonstrate Attitude Control During Construction	7.1 All elements (SPS, MPTS and Antenna) - Demonstrate attitude control of construction base/fabricated article to near full scale as possible in low earth orbit to verify ground based structural models	8
8. Demonstrate Construction During Thermal Cycle of Orbit	8.1 All elements (SPS, MPTS and Antenna) demonstrate construction procedures that meet accuracy and productivity requirements in LEO environment to verify ground based thermal models	6
	8.2 Same as 8.1 GEO environment	6
9. Test for Structural Accuracy and Integrity	9.1 Photovoltaic SPS related	
	9.1.1 Test accuracy of fabricated 1 m deep truss girder requirements (1 m/100 m)	6
	9.1.2 Test accuracy of fabricated 20 m deep truss girder (requirement 1 m/100 m)	8

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
	9.1.3 Test accuracy of fabricated 250 m deep truss girder (requirements 1 m/100 m)	9
	9.1.4 Test each truss girder con- figuration above by	
	9.1.4.1 Axial load TBD at temperature of TBD°K	7
	9.1.4.2 Maintaining 1 m/100 m accuracy with TBD°K temperature difference between cap members	7
	9.2 MPTS Related	
	9.2.1 Maintain 1 arc min accuracy with 5°K temperature dif- ference between cap members	7
	9.2.2 Test for structural strength at a temp of 440°K	8
	9.2.3 Test for structural strength by simulating thermal gradient between center and edge of antenna	9
	9.3 Solar thermal SPS related - Test primary structure for structural integrity at an end load of TBD N at a temp of TBD°K	7

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
10. Demonstrate Structural Repair	9.4 Large antenna related - Test for structural accuracy and strength: ● Parabolic radiometer - load = TBD N - temperature = TBD°K ● Lens comm antenna - load = TBD - temperature = TBD°K	6
	10.1 Photovoltaic SPS related	
	10.1.1 Replace 1 m deep beam element of 20 m deep truss girder	7
	10.1.2 Replace 20 m deep beam element of a 250 m deep truss girder	9
	10.1.3 Replace/repair secondary structure elements: ● Solar blanket supports ● Bus system supports ● Subsystem supports ● Rotary joint supports	7
	10.2 MPTS related	
	10.2.1 Replace Elements of Primary Structure	7

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
	10.2.2 Replace/repair secondary structure elements: • Bus system supports • Subarray supports • Astrionics supports 10.3 Solar thermal SPS related 10.3.1 Replace elements of concentrator primary structure 10.3.2 Replace/repair secondary structure elements • Concentrator facet supports • Bus system supports • Radiator supports • Cavity supports • Rotary joint supports 10.4 Large antenna related 10.4.1 Replace/repair primary structural elements of parabolic reflector and conical lens antenna 10.4.2 Replace/repair secondary structural elements	7 7 7 7 7 7

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
11. Evaluate Structure/Control Interactions	All concepts (SPS, MPTS and Antennas) 11.1 Perform needed vibration testing to verify ground calculations of structural dynamics/attitude control interactions 11.2 Perform needed testing to verify ground calculations of structural/translation control (orbit transfer and station-keeping) interactions	7

OCDA Solar Array Objectives
(Photovoltaic SPS Related Only)

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
1. Demonstrate Array to Structure Installation	1.1 Demonstrate automated deployment and attachment of large area solar blanket to structure in steps: • 20 m x 40 m • 20 m x 300 m • 250 m x 450 m	8
	1.2 Test accuracy (surface roughness of 1 m/100 m) of installation	6
	1.3 Demonstrate automated interface of blanket to bus system	7
2. Demonstrate Reflector Installation	2.1 Demonstrate automated deployment and attachment of large area reflector surface to structure in steps: • 20 m x 40 m • 20 m x 300 m • 250 m x 450 m	
	2.2 Test reflector efficiency after installation ($\eta \geq 85\%$)	7
3. Demonstrate Integrated Construction and Deployment	3.1 Demonstrate sunchronization of solar blanket and reflector installation with structural fabrication at rate of .3m/min	9

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
	3.2 Test performance of integrate finished article	8
4. Demonstrate Space Fabrication of Solar Blanket	4.1 Manufacture crystal or other photovoltaic material	6
	4.2 Integrate into blanket	8
	4.3 Test performance of completed product	7
5. Demonstrate Integrity of Solar Blanket Installation Through Orbit Thermal Cycling	5.1 Test performance and determine failure rates resulting from orbit thermal cycling	6
6. Demonstrate Electrical Integrity of Installed Blanket System	6.1 Operate installed system at 40 kv	7
	6.2 Operate high voltage installed system at GEO to determine plasma effects	8
7. Demonstrate Fault Isolation and Repair Procedures	7.1 Demonstrate installation and functional use of fault isolation system	7
	7.2 Demonstrate safe procedures for replacement or repair of failed solar blanket and reflector surface segments	7

OCDA Power Distribution Objectives

DEMO OBJECTIVE	DEMO REQUIREMENTS	DEMO NEEDED WT
1. Demonstrate Installation of Integral Bus System	1.1 Photovoltaic SPS related	
	1.1.1 Fabricate/install power bus in sync with primary structure at rate of .3 m/min	7
	1.1.2 Conduct high dc voltage tests at 20 and 40 kv dc test for insulation breakdown, corona high voltage transients	8
	1.1.3 Conduct high current density tests 795 amps/cm ² test for local heating, line losses and electrical torques	8
	1.2 MPTS related	
	1.2.1 Install power bus cabling throughout MPTS	7
	1.2.2 Conduct high dc voltage and high current density tests per 1.1.2, 1.1.3	8
	1.3 Solar thermal SPS related	
	1.3.1 Install ac power bus	6
	1.3.2 Conduct high current density tests 500 amps/cm ² test for local heating, line losses and electrical torques	

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
2. Demonstrate Installation of Dedicated Power Control, Switching and Protection System	1.4 Large antenna related - Install ac bus systems for microwave transmitting and receiving systems	5
	2.1 Photovoltaic SPS related - Install and test light weight high power, logic, switching and control system. Test for ARC over, insulation breakdown, and corona effects	8
	2.2 MPTS related - Same as 2.1.1	5
	2.3 Solar thermal related - Install and test lightweight high current capacity logic, switching and central system. Test for local heating and line losses	8
	2.4 Large antenna related - Install and test lightweight power management system with TBD voltage regulation capability	5
3. Demonstrate Installation of Storage	3.1 Install and monitor operation of 30 amp-hr batteries	5

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
4. Demonstrate Installation of Rotary Joint Power Transfer Device	4.1 Photovoltaic SPS related	
	4.1.1 Install rotary joint to transfer power from collector power bus to MPTS. Installation time function of joint type - 2 hr nominal	8
	4.1.2 Verify operation of ball joint drive and suspension system requirement function of orbit for LEO rotation $15^{\circ}/\text{hr} \pm 10^{\circ}$	7
	4.1.3 Verify power transfer requirement 20-40 kvdc and 7.75 amps/cm ² per brush test for insulation breakdown arc over corona, local current heating effects and voltage drop	8
	4.2 MPTS related - Included in 4.1 requirements	
	4.3 Solar Thermal SPS related	
	4.3.1 Install rotary joint between brayton unit/alternator and MPTS. Installation time function of joint	7

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
5. Demonstrate High Voltage Operation	4.3.2 Verify operation of ball joint mech. Operation requirement function of orbit LEO TBD, GEO TBD	7
	4.3.3 Verify power transfer requirement 120-208 vac, 3 @ 400 Hz high current density 5 amps per cm ² /brush	8
	5.1 Photovoltaic SPS related configure a solar array collector to provide 20 kvdc to the power distribution system - Conduct high voltage test of the configuration to investigate and monitor the following phenomena: • Effect of solar storms and flares • Shadowing effects on cell operations • Effect of out-of-eclipse transients • Surface charge and electric dipole effects • Ionization of local materials	8
6. Demonstrate Fault Isolation and Repair	6.1 For each of the above demo requirements, establish and refine maintenance and repair procedures which will verify fault isolation, replacement, repair, and revalidation techniques	7

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
7. Demonstrate Operational Life	7.1 For all of the hardware utilized in verifying the above demo requirements, gather reliability and operational life data through periodic inspections operating time counters, and system for collecting and analyzing data	5

OCDA Power Transmission Objectives

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
1. Demonstrate DC to RF Conversion	1.1 Photovoltaic SPS related covered under 1.2	
	1.2 MPTS related	
	1.2.1 Install and evaluate 20 kv dc to RF (amplitron) converters. Measure: ● Input dc power ● Input ac power ● Efficiency ● Effect variation in input parameters have on operating characteristics ● Output power ● RF gain ● RF noise	8
	1.2.2 Repeat 1.2.1 for 40 kv dc to RF (klystron) converters	8
	1.3 Solar thermal SPS related- covered under 1.2	
	1.4 Large antenna related install and evaluate synchronization and performance of large numbers of RF transmitters	6
2. Thermal Cycling Tests on Waveguides	2.1 Photovoltaic SPS related covered under 2.2	

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
3. Phase Control	2.2 MPTS Related	
	2.2.1 Determine effect or orbital thermal cycles on waveguide, structure and electrical characteristics, i.e., frequency response, resonant frequency and power dissipation	6
	2.3 Solar thermal SPS related covered under 2.2.1	
	2.4 Large antenna related - Determine effect of orbital thermal cycles on structure, beam to beam separation of adjacent transmitters and overall contour control	7
	3.1 Photovoltaic SPS related covered under 3.2	
	3.2 MPTS related	
	3.2.1 Install and evaluate the various phase control systems available for klystrons and amplatron fed power transmission systems using free flying subsatellites and ground rectenna systems	6
	3.2.2 Install and evaluate remote control of amplatron cascade systems	6

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
4. Ionosphere Tests	3.3 Solar thermal SPS related covered under 3.2	
	3.4 Antenna related covered under 3.2	
	4.1 Photovoltaic SPS related - Covered under 4.2 below	
	4.2 MPTS related	
	4.2.1 Evaluate ionosphere on RF signal propagation and RF power transmission losses for transmission at LEO	5
	4.2.2 Evaluate ionosphere losses from GEO and in particular effect on Van Allen Belt on RF propaga- tion, pattern and power transmission	5
	4.3 Solar thermal SPS related covered in 4.2	
	4.4 Antenna related	
	4.4.1 Evaluate ionosphere signal losses from LEO and GEO	5
	4.4.2 Evaluate distortion of signal from GEO (Van Allen Belt Affect)	5

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
	4.4.3 Evaluate noise generated by Van Allen Belt and its effect on low noise receivers and phase control systems.	4
5. GEO Performance (High Voltage and Start)	5.1 Photovoltaic SPS related - Evaluate the SPS high voltage solar configuration and power distribution system performance at GEO Investigate: ● Effect on solar storms and flares ● High voltage transient effects ● Local plasma effects ● Operation of voltage regulation and power transfer devices under high voltage environment 5.2 MPTS Related covered under 5.1 5.3 Solar thermal SPS related same as 5.1 5.4 Antenna related not applicable	8
6. Life Tests	6.1 Evaluate reliability and useful life for all hardware associated with 1-5 above	4

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
7. Integrated Proof-of-Concept	7.1 Perform overall systems performance and operational suitability evaluation	10
8. Demonstrate Transmission to Ground	8.1 Transmit sufficient power (TBD) to ground to determine rectenna efficiencies and side lob effects	8

OCDA Propulsion Objectives

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
1. Install Propulsion Unit for Attitude Control and Station Keeping (SPS, MPTS and Large Antenna Related)	1.1 Demonstrate installation of propulsion system components including: ● Actuators ● Tanks ● Feed system ● Control electronics For advanced high performance devices as well as standard systems	7
	1.2 Measure productivity using ● EVA ● Remote manipulators	9
	1.3 Test integrity of installed system by activating units	8
	2.1 Photovoltaic SPS related	
2. Demonstration Non-Adverse Effects of Exhaust Products on System Performance	2.1.1 Measure exhaust product impact on a solar array operating at high voltage	3
	2.1.2 Measure exhaust product impact on high voltage power distribution system	3
	2.2 MPTS related - Measure exhaust product impact on rf converter performance	3

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
3. Demonstrate Fault Isolation and Repair Procedures (SPS, MPTS and Large Antenna Related)	2.3 Solar Thermal Related - Measure exhaust product impact on reflector performance and life	3
	2.4 Large antenna related - Measure exhaust product impact on antenna performance	3
	3.1 Replace/repair elements of propulsion system including: ● Actuators ● Tanks ● Feed System ● Control Electronics	5
	3.2 Test fault isolation system	3

OCDA Stabilization and Control Objectives

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
1. Control of Large Flexible Bodies Using Centralized and Distributed Systems	1.1 Install and evaluate centrally located attitude control systems designed to hold large flexible arrays to within $\pm$ TBD degrees 1.2 Install and evaluate distributed attitude control system designed to hold large flexible arrays to within $\pm$ TBD degrees	7
2. Surface Contour Control	2.1 Install and evaluate contour control system designed to maintain contour from $\lambda/50$ to $\lambda/10$ accuracy	8
3. Point One Large Mass With Respect to Second Mass	3.1 Install and evaluate system including rotary joint to point one mass with respect to a second within 1 arc minute 3.2 Determine stability of system	7
4. Installation of Equipments		

OCDA Reflector Mirror Facets Objectives

DEMO OBJECTIVES	DEMO REQUIREMENT	DEMO NEEDED WT
1. Placement and Installation	1.1 Install and evaluate installation techniques and procedures of mirror facets to primary structure installation time TBD hr	9
	1.2 Measure accuracy of contour of deployed facets	8
2. Pointing and Control on Flexible Body	2.1 Install and evaluate automated control system for maintaining position and accuracy of reflecting surface	10
3. Fault Isolation and Repair	3.1 Evaluate techniques, equipment and procedures for: ● Fault isolation ● Removal ● Repair ● Revalidation of facets and/or facet control system	6

OCDA Radiator Objective

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
1. Positioning and Assembly of Radiator Elements	1.1 Install and evaluate assembly rate of radiating subsections. Assembly rate TBD	
	1.2 Evaluate equipment used to assemble radiating subsections	7
	1.3 Mate subsections to thermal panels	6
	1.4 Leak check radiator system lead rate TBD	6
2. Gas Tight Joints	2.1 Assemble, mate and evaluate radiator to heat exchanger loop	6
	2.2 Lead check complete coolant loop	
	2.3 Evaluate techniques equipment and procedures required to install and check out radiator/heat exchange system	5
3. Fault Isolation and Repair	3.1 Evaluate techniques, equipment and procedures for:	4
	● Fault isolation ● Leak detection ● Removal ● Repair ● Revalidation of completed cooling loop	

OCDA Thermal Cavity Objectives

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
1. Positioning and Assembly	1.1 Install and evaluate techniques and procedures for maneuvering, positioning and assembly of large cavity panels	8
	1.2 Evaluate handling, transportation and joining equipment and tools	
2. Gas Tight Joints	2.1 Install and evaluate solar cavity absorber assembly and heat - transfer distribution system	6
	2.2 Leak check heat transfer distribution system leak rate (TBD)	6
3. Cavity Performance Through Construction	3.1 Evaluate the performance of the solar collector/absorber system throughout sun/shade cycles	10
	3.2 Measure temperature variation at outlet and inlet manifolds during sun/shade cycles	7
	3.3 Measure critical component temperatures during sun/shade cycles	7
	3.4 Measure pressure drops in system	6

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
4. Control With Rotating Machinery	4.1 Install rotating machinery turbines and alternators and complete heat transfer distribution system tests	8
	4.2 Measure the overall performance of system throughout sun shade/cycle. Measure variations in voltage, current temperature, pressure drops throughout system	10

OCDA Large Mirror Surface Objectives

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
1. Positioning and Assembly	1.1 Install and evaluate techniques equipment and procedures for handling, positioning, and attaching large mirror segments to primary structural	8
2. Contour Control	2.1 Evaluate techniques and equip- ment for alignment of reflective surface segments	8
3. Efficiency Measurement	3.1 Measure efficiency of reflectors	5
4. Life Testing	4.1 Determine useful life of reflectors in space environment	4

OCDA Assembly Operations Objectives

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
1. Initial Placement of Construction Platform	1.1 Evaluate operational aspects related to initial placement of construction platform	8
	1.1.1 Update and refine assembly procedures	6
	1.1.2 Evaluate safety aspects of assembly OPS	7
2. Site Logistics	2.1 Evaluate logistics system	7
	2.1.1 Update and refine logistics plans	6
	2.1.2 Update and refine detailed logistics procedures	6
3. Resupply and Storage	3.1 Evaluate resupply system and facilities - Update and modify resupply and storage plans	6 5
4. Site Communications	4.1 Evaluate adequacy of site communications systems	5
	4.1.1 Evaluate OCDA work station to orbiter communica- tions system with respect to monitoring and control of OCDA construction and test operations	5

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
	4.1.2 Evaluate OCDA work station to ground communications system with respect to monitoring a control of OCDA construction and test operations	5
5. Site Lighting System	5.1 Evaluate adequacy of OCDA lighting system	5
	5.1.1 Evaluate adequacy of work area lighting	5
	5.1.2 Evaluate adequacy of route and emergency lighting system	5
	5.1.3 Evaluate transportation docking lighting	4
6. Radiation Safety (GEO)	6.1 Evaluate radiation protection	6
	6.1.1 Evaluate radiation protection devices	5
	6.1.2 Evaluate radiation protection procedures	5
	6.1.3 Measure actual radiation environment and modify radiation protection specs	5
7. Productivity Goals	7.1 Evaluate productivity	8
	7.1.1 Measure, evaluate and modify productivity goals	8

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
8. Remove Manipulators	7.1.2 Recommend hardware, software, and procedural changes required to improve productivity goals	7
	8.1 Evaluate man/machine interface related to remote manipulator and cherry picker	7
	8.1.1 Evaluate operation in artificial lighting	7
	8.1.2 Evaluate logistics capability of manipulator	7
	8.1.3 Evaluate ability to install, remove and make adjustments with manipulator or cherry picker	6
9. Space Fabrication (Auto Assembly)	9.1 Evaluate operation of automatic space fabrication hardware	8
	9.1.1 Evaluate operation of automatic assembly equipment	8
	9.1.2 Evaluate and modify procedures used for automatic space fabrication and assembly	8

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
10. Use of EVA	10.1 Evaluate the Use of EVA for: ● Joining beams ● Installing subsystems ● Monitoring assembly ● Equipment removal ● On station repair ● Servicing ● Testing and calibration ● Fault isolation ● Directing remote operations	7
11. Fault Isolation and Repair of Construction Equipment	11.1 Evaluate techniques and procedures for troubleshooting, disassembly and repair of construction equipment, i.e., fabrication modules, manipulator systems, cherry pickers and other transportation equipment	6

OCDA Processes Objectives

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
1. Fastener Options	1.1 Evaluate the various joining processes for metals and composites used in space construction. Processes to be evaluated include: ● Welding ● Bonding ● Mechanical	7
2. Fabrication in Metallics and Nonmetallics	2.1 Evaluate structural fabrication: ● Metallics: aluminum, steel, titanium, magnesium ● Nonmetallics: graphite/epoxy, graphite/polymide, graphite/polyethersulfone 2.2 Evaluate visability of growing crystals	7 6

OCDA Mission Operations Objectives

DEMO OBJECTIVE	DEMO REQUIREMENT	DEMO NEEDED WT
1. Communications	1.1 Evaluate local orbital communications systems between OCDA work sites and Shuttle orbiter	5
	1.2 Evaluate remote communications data and command/control link between OCDA/Shuttle and ground communications and control network	5
2. Remote Control From Ground	2.1 Evaluate the techniques, procedures and constraints associated with ground remote monitor and control of: • Space fabrication modules • Manipulators • Free flying teleoperator • OCDA boom/traveler logistics system	8
3. Mission Planning	3.1 Evaluate plans, procedures and facilities required to plan and support space fabrication, assembly and construction operations	5

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